THE BDM CORPORATION

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OSSA SPACE STATION SERVICING DATA BOOK II

PART I

PREPARED FOR THE OFFICE OF SPACE SCIENCE AND APPLICATIONS (OSSA), NASA HEADQUARTERS

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This report has been prepared for the Office of Space Science and Applications (OSSA), NASA Headquarters

FOREWORD

This report has been prepared for the Office of Space Science and Applications (OSSA), NASA Headquarters, by the BDM Corporation under NASA Contract Number NASW-4152. The report identifies the top level Space Station payload servicing requirements of the OSSA missions which are currently planned to be candidates for servicing from the Space Station. These top level requirements are based on a survey and an analysis of the servicing needs of the candidate OSSA missions. Detailed descriptions of the missions and their servicing needs are presented.

The document has been released to provide additional insight into OSSA's requirements for servicing by the Space Station System. The formal requirements under configuration control by OSSA are submitted to the Space Station Program through the OSSA Space Station Mission Requirements Database.

The payload servicing data presented here represents requirements and schedules corresponding to Payload Office planning as of October, 1987. OSSA is grateful to the many NASA planners, study managers, and project representatives who contributed their time and knowledge to make this report complete and accurate.

The data presented in this volume should provide useful representations of individual OSSA payload requirements. The following important considerations should, however, be recognized when working with this information:

(1) Many of the OSSA payloads discussed herein have not received formal approval to progress to their development phases,

(2) Such approvals require the concurrence of both top NASA Management and external funding agencies,

(3) Data presented is subject to change due to the continuing evolution of the payloads, the Space Station Program, and the Space Transportation System.

(4) No integrated requirements or timelines have been calculated to assess total demand in Space Station resources, and

(5) No checks have been performed to match payload office needs with Space Station resources/capabilities. Data presented are for planning purposes only.

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CHAPTER I
INTRODUCTION

A. OBJECTIVE

The objective of this report is to present a compilation of on-orbit servicing information for OSSA payloads which are candidates for flight under the Space Station Program. These payloads were selected by OSSA as potential drivers for establishing servicing requirements at the Space Station.

B. BACKGROUND

During the Space Station era, several different types of payloads will need to be serviced on-orbit by the Space Station Program. The following types of payloads are likely to be included:

(1) Space science and applications experiments,

(2) Applications (e.g., weather) satellites,

(3) Civilian and military communications satellites,

(4) Other commercial or military payloads,

(5) International payloads, and

(6) Technology demonstration experiments.

The envelope of servicing requirements for this total mission set will help define the servicing capability required of the Space Station Program. This report addresses the servicing requirements for the first set of missions above, those of OSSA.

Since the publishing of the first volume of the OSSA Servicing Data Book (November 6, 1985), the concept of on-orbit servicing has continued to grow in importance. Payload "design-for-servicing" from the Space Station is receiving increasing emphasis for many planned OSSA missions in much the same way that the Hubble Space Telescope (HST) design was influenced by planned servicing with the STS Orbiter. Many of the payloads discussed in this edition of the Data Book reflect in their design this heightened awareness of servicing by the SS Program.

C. WHAT IS ON-ORBIT SERVICING?

On-orbit servicing may be defined as the manipulation or control of a payload by astronauts and/or robotics to effect a positive change in the condition of that payload. On-orbit servicing is classified into three broad categories: planned servicing, anticipated contingency servicing, and unanticipated contingency servicing.

This classification scheme has been developed to encompass the various servicing categories, i.e., whether the payload has been designed for service (or not) and whether the service has been scheduled (or not). The possibilities are illustrated in Figure I-1.

In this report only planned servicing is addressed. That is, the term "servicing" as used here means planned servicing. However, for completeness each category is described below.

1. Planned Servicing

A planned servicing is one which is both designed for and scheduled. Planned servicing is needed to extend the life or improve the performance of an existing payload. A variety of actions will be possible, including:

(1) Payload transfer to different (longer lived or more suitable) orbits,

(2) Replenishment of consumable items such as propellants, cryogenic coolants, pressurants, food and water (for use in pressurized modules) etc.,

(3) Substitution of new systems for currently utilized systems (for example, the replacement of existing scientific instruments with higher performance instruments),

(4) Replacement of degraded systems,

(5) Refurbishment (cleaning, re-alignment, calibration, etc.), and

(6) Repair of degraded systems,

Such actions will be considered a routine part of the mission and will be taken into account in the design of the payload. They will usually be scheduled long in advance to take advantage of favorable orbit alignments (free-flyer rendezvous and retrieval) or of STS support flight schedules.

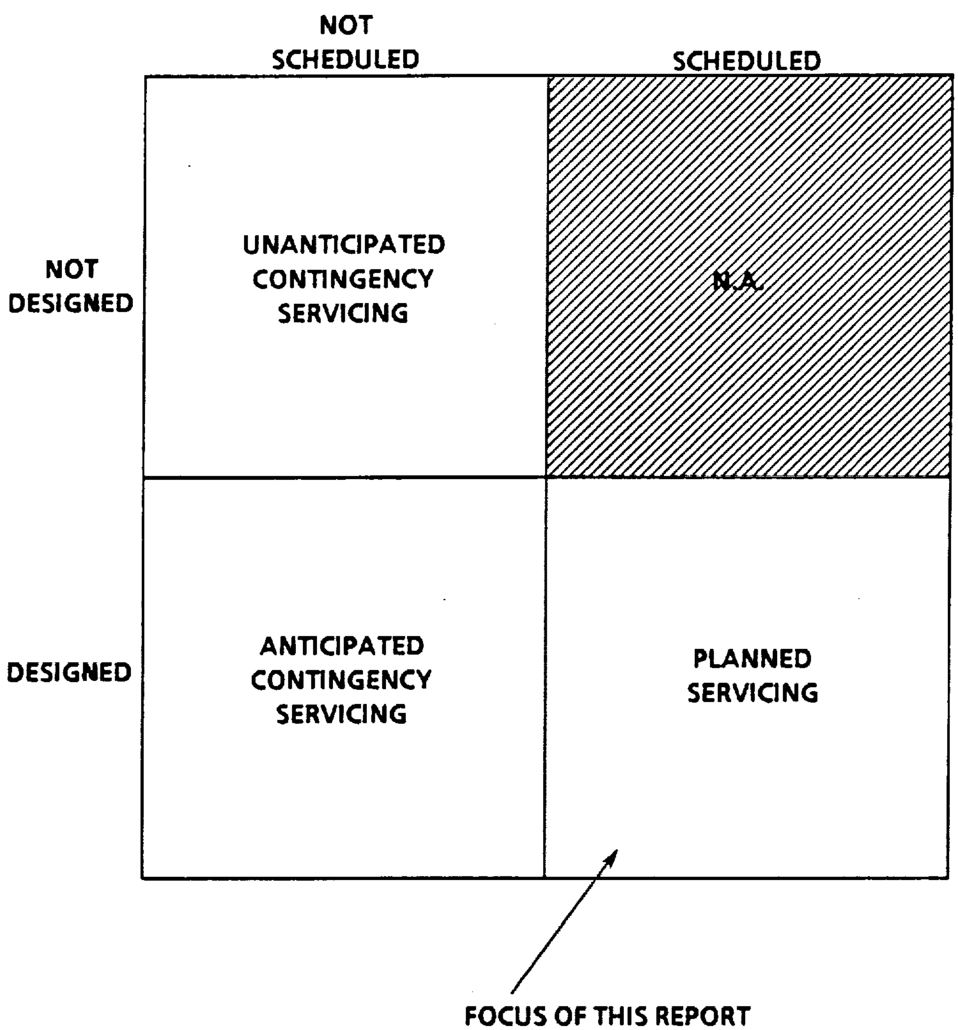

Figure I-1. Type of Servicing

C0200*7D-01

2. Anticipated Contingency Servicing

An anticipated contingency servicing, which is designed for but unscheduled, will occur after a payload/spacecraft failure or system degradation and will include actions which were considered possible and planned for before launch. An example would be unit replacement following a random failure. Failure diagnosis would be necessary before final plans for such contingency actions could be made. The actions would be implemented as opportunities presented themselves (for example, a free-flyer would be retrieved when opportune to do so, even though repairs might have to wait weeks or months until a spare unit was delivered to the Space Station from the ground).

3. Unanticipated Contingency Servicing

An unanticipated contingency servicing, which is neither designed for nor scheduled, would consist of opportunistic use of on-board resources to service failed or degraded payloads.

4. General Guidelines

The boundary between payload servicing and payload operational activities is not always clear. In addition, it is sometimes difficult to decide whether certain servicing-related activities should be associated with specific payloads or treated as a routinely available Space Station capability. For this report the following general guidelines have been adapted, although some activities must be treated on a case-by-case basis.

(1) Payload initial launch and final retrieval missions are considered operational activities and are not included in the payload descriptions as servicing missions (though basic information about them is provided for completeness).

(2) On-orbit assembly is considered servicing and appropriate data estimates have been included, where possible, for those payloads requiring such assembly.

(3) OSSA payloads are dependent on SS Program facilities to carry out the desired servicing activities. These facilities include the SS Servicing Facility (SF), the Mobile Servicing Center (MSC),

Consumable Tankers (or tank farms), various manipulators such as the Mobile Remote Manipulator System (MRMS), and, in the case of free-flyers, the Orbital Maneuvering Vehicle (OMV).

(4) The provision and storage of certain payload consumables (specifically hydrazine, water, and superfluid helium) are assumed to be Space Station Program responsibilities. The requirements for these consumables (mass, volume, schedule) are indicated by the Payload Offices and estimates are made of the needed servicing times are made.

(5) The provision and storage of other payload consumables that are replenished by changing out empty containers for full containers are considered payload responsibilities.

(6) The STS transport and SS storage of payload servicing material (estimated masses and volumes) are associated with the payload. In some cases, the Payload Office has specified that it will provide a special carrier for these materials. In other cases the Payload Office has elected to utilize SS-provided logistics modules. When a special carrier is indicated, estimates of its mass and volume are included with similar data describing the servicing materials.

D. ORBITAL SERVICEABLE UNIT (OSU)

An Orbital Serviceable Unit (OSU) is a generalization of the HST-derived Orbital Replacement Unit (ORU). An OSU is any payload/spacecraft unit subject to service. A typical example of an OSU is the command and data handling unit of a multi-mission spacecraft module. This unit is also an ORU. Examples of OSUs which are not ORUs include the optical system of a telescope (which may be cleaned on-orbit), the propellant tank of a Multi-mission Spacecraft (if refueled but not replaced), or any complex non-removable unit which is subject to on-orbit repair.

Most of the OSUs identified in this report are serviced either by a changeout process (for ORUs) or by consumable replenishment. Other types of OSU servicing (repair or cleaning for example) have been considered by the payload offices but have not been identified as a servicing requirement. Consequently the term OSU appears infrequently in this report. It may, however, see wider use as future servicing capabilities evolve.

E. ORBITAL SERVICING ACTIVITIES (OSAs)

An Orbital Servicing Activity (OSA) is a specific servicing activity, such as replacement, calibration, refueling, resupply, repair, assembly, deployment, retrieval, or reboosting.

The number of OSAs can be very large, depending on the granularity of the definitions chosen. OSAs such as "perform consumable replenishment" indicate coarse granularity and a relatively small set of OSAs. On the other hand, OSAs at the level of "apply wrench" would result in a much greater number of activities. For this Data Book, BDM has specifically defined certain high level OSAs to assist in standardizing engineering estimates and to provide an audit trail for calculated parameters. Table I-1 provides a list of the 14 basic OSAs used in this report. Appendix C describes explicit estimating assumptions for each OSA.

It should be noted that the selection and definition of activities which describe "servicing" within the community have not been standardized

TABLE I-1. BASIC ORBITAL SERVICING ACTIVITIES

1. STS brings Servicing Materials from Earth
2. Unloading of Servicing Material from STS to SS
3. OMV or OMV + OTV Brings Payload from Orbit to SS or STS
4. Payload Berthing-Related Activities at STS or SS
5. Transport of Servicing Materials from SS Servicing Facility to Payload and Back
6. ORU Changeout
7. Replenishment of Consumables
8. Payload Deberthing-Related Activities at STS or SS
9. OMV or OMV + OTV Deploys Payload to Orbit
10. Loading of Servicing Materials from SS to STS
11. STS Takes Servicing Materials to Earth
12. Rack Changeout of Pressurized Module Payload
13. In-Situ Servicing Activities
14. On-Orbit Payload Assembly

and in fact may differ from one analysis to another. The activities and definitions selected in this Data Book have attempted to reflect the most frequent and common usage of the terms involved.

The OSAs discussed in this report involve combinations of IVA, EVA, and robotics. The development of robotic devices to do some of the simpler OSAs remotely will eventually reduce the overall EVA time needed for servicing. However, the introduction of robotics for servicing is likely to be gradual, since many of the OSAs are quite complex and since, for even simple activities such as OSU replacement, the design of the replaceable units may have to be modified to make them compatible with robotic devices.

F. PAYLOAD CATEGORIES

The payloads whose servicing requirements have been analyzed can be grouped into five types as follows:

(1) free-flyers,

(2) co-orbiting platforms,

(3) polar platforms,

(4) attached payloads, and

(5) scientific laboratory modules.

Note that co-orbiting platforms and polar platforms are special cases of the free-flyer category, and the scientific laboratory modules are special cases of attached payloads. The servicing characteristics for each payload type are described generically below:

1. Free-Flyers

The free-flyer missions typically range from the fully capable observatory-type satellites, with planned lifetimes of up to fifteen years, to the small, relatively short duration Explorer missions. The spacecraft have features such as solar arrays, onboard data collection and formatting systems, uplink (command) and downlink (data) telemetry subsystems, and frequently, their own propulsion subsystems for orbital positioning.

The Space Station Spartan (3S), with plans to fly in close proximity to the Space Station, is an important special subclass of free-flyers. It will be retrieved routinely by the Space Station, reconfigured, and relaunched. Each science mission will last from a few weeks to a few months with servicing performed at the Space Station between science missions.

2. Co-orbiting Platforms

Co-orbiting platforms such as SIRTF can be considered similar to the free-flyers from a servicing perspective; however, they may contain systems or components common to each other, common to the polar platforms, and possibly common to those in use on the Space Station itself. This commonality may provide additional flexibility in servicing these missions, since, presumably, some of the spares for the common platform systems will be held on the Space Station and maintenance will not be dependent upon the arrival of spares on the Shuttle.

3. Polar Platforms

Polar Platforms may have many spacecraft subsystems in common with the Co-Orbiting Platforms although their high orbital inclination will require the use of the Space Shuttle rather than the Space Station for on-orbit servicing support. Since the Polar Platform ORUs may be similar, if not identical to those of the Co-Orbiting Platforms, these two types of systems may have similar servicing requirements. The limited EVA time available using the Shuttle may, however, have special influence on the design of the Polar Platforms. As a result, current platform planning reflects increasing use of on-platform robotics for instrument changeout.

Servicing of polar platform science instrument payloads is expected to consist of planned and contingency instrument replacement and reconfiguration, instrument upgrade, component replacement, resupply of applicable instrument consumables, and possible repair of modular electronics systems or other easily accessible on-orbit instrument subsystems. Potential calibration, verification, and checkout activities will also be part of polar payload servicing. If the polar platforms

contain integral propulsion, servicing will involve propellant resupply, possibly through propulsion subsystem changeout.

4. Attached Payloads

These payloads are attached to the truss of the Space Station through the use of a Station Interface Adapter (SIA) and a Payload Interface Adapter (PIA). Attached payloads will in general use power, communications, and thermal control provided by the Space Station. Pointing requirements range from arc-seconds to a few degrees. Orientation may be earth pointing, anti-earth pointing, sun pointing, or celestial.

Most of these payloads will have unique systems (telescopes, detectors, etc.) which are intended to have relatively long lives and are of such a nature that spares would not be kept routinely on the Space Station. Thus, failures of these systems would typically necessitate the delivery of spares on the next available Shuttle.

5. Scientific Laboratory Modules

The scientific laboratory modules will be incorporated in the habitable portion of the Space Station and will provide facilities similar to those of Earth-based laboratories. Each module may have dozens or hundreds of items of associated routine laboratory equipment which, in many instances, would not significantly differ from Earth-used equipment.

At present, two laboratory modules are envisioned: the Life Sciences Research Facility (LSRF), and the Microgravity and Materials Processing Facility (MMPF). All laboratory servicing will occur within the pressurized module environments via IVA. LSRF servicing activities will occur both within the LSRF itself, and external to the LSRF (but within the habitable environment) when conducting resupply, replacement, or associated servicing.

The MMPF considers all activities which occur within the MMPF laboratory to be operational, regardless of their specific nature. Hence, servicing activities for MMPF are confined to those activities which require entering or exiting the facility. These include transferring supplies into the MMPF, removing/storing wastes or processed materials, and transferring double, single, or partial equipment racks into and out of the facility for internal reconfiguration.

Many of the resupply actions for the scientific laboratories will be through the normal SS Logistics Module supply activity.

G. PAYLOAD SUMMARY

The payloads covered in this edition of the Data Book are presented alphabetically by abbreviation in Table I-2. This table also includes a brief description of each payload and a summary of the servicing activities for that payload. The second column indicates whether the payload is an attached payload (A), a free-flyer (FF), a polar platform (P), a co-orbiting platform (C), or a laboratory module (L).

As a rough measure of the degree to which the payloads have been defined, the current phase of development of each payload is indicated in column 3. The categories are Pre-phase A (Pre-A), Phase A, Phase B, and Phase C/D. Pre-phase A is the conceptual study phase in which requirements documents are produced identifying scientific objectives, technical concepts, and preliminary scoping. Phase A involves analysis of alternative system designs, preparation of a preliminary project plan, and feasability studies. Phase B encompasses preliminary design and verification of critical systems and subsystems. It concludes with the choice of a single project approach and the development of a detailed schedule and procurement approach. Phase C/D refers to a stage where developmental funding has been approved and implemented.

In Tables I-3 and I-4, the payloads are associated with their SAAX numbers. Table I-3 is organized alphabetically by abbreviation, while the data in Table I-4 is ordered numerically by SAAX number.

In Table I-5 a comparison of the payloads of Book I and those of this Data Book is provided. In the current version some of the earlier payloads have been dropped, others have been added, and still others have changed names. In every case, payload information has changed since 1985, and in some cases the changes have been extensive.

TABLE I-2. OSSA PAYLOAD SUMMARY

PAYLOAD	TYPE	PHASE	DESCRIPTION	SERVICING
ASTRO	A	C/D	ASTRO applies ultraviolet imagery, spectroscopy & polarimetry to the study of faint objects.	None
ASTROMAG	A	PRE-A	Astrophysics Magnet Facility. Uses superconducting magnet for high energy Astrophysics.	*On-Orbit Assembly *Resupply Helium *Replace Science Instruments
ATF	A	PRE-A	Astrometric Telescope Facility. Optical telescope designed to search for planetary systems & support additional Astrophysics.	*On-Orbit Assembly *Replace Mechanical or Electronic Components
AXAF	FF	B	Advanced X-Ray Astrophysics Facility. The X-Ray Great Observatory.	*Changeout ORUs and Science Instruments
CDCE	A	A	Cosmic Dust Collection Experiment. Measures orbital parameters of impacting extraterrestrial material.	*Changeout Impacted Cells
CRNE	A	C/D	Cosmic Ray Nuclei Experiment. Studies energy spectra and propagation of Cosmic Rays. Electronic Counter Telescope.	None
Eos	P	A	Earth Observing System. Obtains detailed physical, chemical, & biological studies of earth & atmosphere through four polar platforms.	*ORU Changeout *Science Instrument Replacement
EP	FF	C/D	Explorer Platforms. Will carry various instrument packages to perform Astrophysics studies of a wide variety of objects.	*Changeout Science Instrument. First exchange is XTE for EUVE
GRO	FF	C/D	Gamma Ray Observatory. This Great Observatory will study gamma ray emitting objects.	*Replace 1000 kg of Hydrazine
HH/ERBE	A	PRE-A	Hitchhiker Earth Radiation Budget Experiment. Hitchhikers allow small science and engineering payloads to conduct their intended missions. ERBE investigates radiative output of the tropics over time.	None
HRSO	A	PRE-A	High Resolution Solar Observatory. Addresses fundamental solar phenomena.	*Replace co-observing ultraviolet science instrument
HST	FF	C/D	Hubble Space Telescope. This visible light Great Observatory will allow study of objects up to 14 billion light years away.	*Changeout ORUs
LAMAR	A	B	Large Area Modular Array. Performs sensitive cosmic x-ray observations in the 0.10 - 10.0 KEV energy range.	*Replace gas module.
LASERCOM	A	PRE-A	Laser Communications Engineering Test. Tests acquisition and tracking with telescope, transmitter, and receiver.	None
LAWS	A	A	Laser Atmospheric Wind Sounder. Provides a direct measurement of the tropospheric wind field, via Doppler-LIDAR Techniques.	*Changeout of ORUs

TABLE I-2. OSSA PAYLOAD SUMMARY (continued)

PAYLOAD	TYPE	PHASE	DESCRIPTION	SERVICING
LDR	FF	PRE-A	Large Deployable Reflector. Will conduct submillimiter-infrared astronomical observation of various astrophysical phenomena in the 30-1000 micron region.	*On-orbit assembly *Replenish liquid helium
LSRF	L	A	Life Sciences Research Facility. Pressurized module which will provide a laboratory in space for basic research in the Life Sciences.	*Resupply of consumables and removable of waste
MMPF	L	A	Microgravity & Material Processing Facility Pressurized module which provides opportunities to process very pure & new forms of materials in a controlled microgravity environment.	*Resupply of consumables and removable of waste
PIMS	A	A	Plasma Interaction Monitoring System. Measures induced space environment around the Space Station and the interactive effects between the Space Station and this enivronment.	None
POF	A	A	Pinhole Occulter Facility. Uses x-ray & corna-graph equipment to study plasma dynamics.	*Changeout two proportional counters
SBAR	A + FF	PRE-A	Space-Based Antenna Range. Will test experimental communications links, antenna characteristics, & other functions of spacecraft prior to final orbit placement.	*Changeout test instrument & subsystem modules *Replenishment of hydrazine
SIRTF	FF	A	Space Infrared Telescope Facility. This Great Observatory will study astrophysical features/phenomena in the infrared region.	*Resupply liquid helium *Replace ORUs
SRI	A	PRE-A	Search and Rescue Instruments	*TBD
3S	FF	PRE-A	Space Station Spartan. This system is a relatively low cost system which allows free flying missions to originate from SS.	*Changeout of science Instrument *Replenish hydrazine *Changeout ORUs
STO/PIG	A + FF	A	Solar Terrestrial Observatory: Plasma Instrument Group. See STO/SS.	*Replace ORUs Replenish Gas
STO/POP	P	A	Solar Terrestrial Observatory: Polar Orbiting Platform. See STO/SS.	*Replace ORUs Replenish Gas
STO/SIG	A + FF	A	Solar Terrestrial Observatory: Solar Instrument Group. See STO/SS.	*Replace ORUs *Replace film cannisters
STO/SS	A + FF	A	Solar Terrestrial Observatory: Space Station. Has a variety of instruments to study solar activity & the physical processes coupling the atmosphere, the magnetosphere, & the sun.	*Changeout ORUs *Replace Film
TRIS	A	A	Tropical Region Imaging Spectrometer. Studies biological & physical processes of tropical regions	*Replace ORUs (cooling system)
TRMM	A	A	Tropical Rainfall Measurement Mission. Measures rain-fall in the tropics to increase our understanding of tropical energetic & hydrologic processes.	None
XGP	FF	PRE-A	Experimental GEO Platform. Allows development & demonstration of enabling communications & science payload & antenna technologies.	*Unfurl & test XGP at SS *Replenish hydrazine (in SITU) *Replace ORUs (in Situ)

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TABLE I-3. OSSA PAYLOADS ALPHABETICALLY BY ABBREVIATION

ABBREVIATION	SAAX	TYPE*	NAME
1. ASTRO	N.A.	A	Astro
2. ASTROMAG	0021	A	Astronomical Magnet Facility
3. ATF	0115	A	Astrometric Telescope Facility
4. AXAF	0017	FF	Advanced X-Ray Astrophysics Facility
5. CDCE	0012	A	Cosmic Dust Collection Experiment
6. CRNE	0001	A	Cosmic Ray Nuclei Experiment
7. Eos	0202	P	Eos
8. EP	0027	FF	Explorer
9. GRO	0013	FF	Gamma Ray Observatory
10. HH/ERBE	0250	A	Hitchhiker Earth Radiation Budget Experiment
11. HRSO	0010	A	High Resolution Solar Observatory
12. HST	0012	FF	Hubble Space Telescope
13. LAMAR	N.A.	A	Large Area Modular Array of Reflectors
14. LASERCOM	N.A.	A	Laser Communications Engineering Test
15. LAWS	N.A.	A	Laser Atmospheric Wind Sounder
16. LDR	0020	FF	Large Deployable Reflector
17. LSRF	0307	L	Life Sciences Research laboratory
18. MMPF	0401	L	Microgravity Materials Processing Facility
19. PIMS	N.A.	A	Plasma Interaction Monitoring System
20. POF	0011	A	Pinhole Occulter Facility
21. SBAR	0501	A&FF	Space-Based Antenna Range
22. SIRTF	0004	C	Space Infrared Telescope Facility
23. SRI	N.A.	A	Search and Rescue Instruments
24. 3S	0022	FF	Space Station Spartan
25/ STO/PIG	N.A.	A	Solar Terrestrial Observatory
26. STO/POP	0225	P	Solar Terrestrial Observatory (Polar Platform)
27. STO/SIG	N.A.	A	Solar Terrestrial Observatory
28. STO/SS	0207	A&FF	Solar Terrestrial Observatory (SS Attached)
29. TRIS	N.A.	A	Tropical Region Imaging Spectrometer
30. TRMM	0251	A	Tropical Rainfall Measurement Mission
31. XGP	0502	FF	Experimental GEO Platform

*
A = Attached;
C = Co-orbiting Platform;
FF = Free-Flyer;
L = Laboratory;
P = Polar Platform

TABLE I-4. OSSA PAYLOADS NUMERICALLY BY SAAX NUMBER

SAAX	ABBR.	TYPE*	NAME
N.A.	ASTRO	A	Astro
N.A.	LAMAR	A	Large Area Modular Array of Reflectors
N.A.	LASERCOM	A	Laser Communications Engineering Test
N.A.	LAWS	A	Laser Atmospheric Wind Sounder
N.A.	PIMS	A	Plasma Interaction Monitoring System
N.A.	SRI	A	Search and Rescue Instruments
N.A.	STO/PIG	A	Solar Terrestrial Observatory
N.A.	STO/SIG	A	Solar Terrestrial Observatory
N.A.	TRIS	A	Tropical Region Imaging Spectrometer
0001	CRNE	A	Cosmic Ray Nuclei Experiment
0004	SIRTF	C	Space Infrared Telescope Facility
0010	HRSO	A	High Resolution Solar Observatory
0010	POF	A	Pinhole/Occulter Facility
0012	HST	FF	Hubble Space Telescope
0013	GRO	FF	Gamma Ray Observatory
0017	AXAF	FF	Advanced X-Ray Astrophysics Facility
0020	LDR	FF	Large Deployable Reflector
0021	ASTROMAG	A	Astronomical Magnet Facility
0022	3S	FF	Space Station Spartan
0027	EXP	FF	Explorer
0112	CDCE	A	Cosmic Dust Collection Experiment
0115	ATF	A	Astrometric Telescope Facility
0202	Eos	P	Eos
0207	STO/SS	A&FF	Solar Terrestrial Observatory (SS Attached)
0225	STO/POP	P	Solar Terrestrial Observatory (Polar Platform)
0250	HH/ERBE	A	Hitchhiker Earth Radiation Budget Experiment
0251	TRMM	A	Tropical Rainfall Measurement Mission
0307	LSRF	LL	Life Science Research Facility
0401	MMPF	L	Microgravity Materials Processing Facility
0501	SBAR	A&FF	Space-Based Antenna Range
0502	XGP	FF	Experimental GEO Platform

*
A = Attached;
C = Co-orbiting Platform;
FF = Free-Flyer;
L = Laboratory;
P = Polar Platform

TABLE I-5. COMPARISON OF BOOK I AND BOOK II PAYLOADS

BOOK I	BOOK II	COMMENTS
ASOPOF	POF	"Advanced Solar Observatory" dropped in title.
ASOSOT	HRSO	HRSO is a smaller version of the Advanced Solar Observatory: Solar Optical Telescope
AT	ATF	"Facility" added to title.
AXAF	AXAF	
CDCE	CDCE	
CRNE	CRNE	
EOS	EOS	
ERBE	-	ERBE merged with HH.
EXP	EP	Explorer renamed Explorer Platform (EP).
GRO	GRO	
HH	HH/ERBE	ERBE merged with HH.
HST	HST	
LDR	LDR	
LP	-	"Leased Platform" dropped.
LSF	LSRF	"RESEARCH" added to title.
MMPF	MMPF	
SBAR	SBAR	
SIRTF	SIRTF	
SMF	ASTROMAG	ASTROMAG was formerly "Superconducting Magnet Facility".
3S	3S	
SSM	-	Solar Maximum Mission dropped.
STO	STO/SS	Abbreviation change.
STOPP	STO/POP	Abbreviation change.
TREP	TRMM	"Experiment Package" changed to "Measurement Mission".
XGP	XGP	
-	ASTRO	ASTRO added.
-	LAMAR	LAMAR added
-	LASERCOM	LASERCOM added
-	LAWS	LAWS added
-	PIMS	PIMS added
-	SRI	SRI added
-	STO/PIG	STO/PIG added
-	STO/SIG	STO/SIG added
-	TRIS	TRIS added

H. PROCEDURES

BDM's approach to the compilation of servicing data and the derivation of top level servicing requirements remains basically the same as the approach taken for Book I, but with significant enhancements. The major procedures are discussed below.

1. Expansion of Data-Format

The Book I data format, originally based on experience with the Hubble Space Telescope servicing plans and the NASA Langley database, has been expanded and refined considerably for Book II in an effort to reflect the increased attention to servicing by many of the payload offices. Section J below provides an overview of this new format, and Appendix C contains a detailed discussion of what each entry should be.

2. The Strawman Concept

In this Data Book, one or more typical or "strawman" servicing missions are explicitly developed for each serviceable payload. The set of strawmen for a payload is intended to characterize all of the planned servicing activities during the lifetime of that payload.

The procedure of using such a strawman mission is an outgrowth of the example servicing missions used to calculate crew-hour time estimates in Section 1 of Book I, where baseline activities such as "replace large component" can be found. The use of the strawman concept in Book II is considered advantageous because:

(1) Uncertainties about final requirements can be checked against basic assumptions found in the selection of strawmen to provide traceability of data,

(2) Other requirements (in addition to crew times) are now associated with individual strawmen. Examples of these requirements include estimates of flight support equipment (FSE) and consumables,

(3) A broader range of servicing activities have been defined, e.g., on-orbit assembly (for several payloads), superfluid helium replenishment, and transport and storage of servicing materials.

(4) A greater number of servicing parameters have been estimated, including robotic time and STS up/down mass and volume of servicing materials.

It is important to observe that the word "strawman" is used here to denote a "typical" servicing scenario rather than one of a set of mutually exclusive servicing alternatives to be chosen or rejected.

The OSAs in Table I-1 may be used to describe strawmen servicing scenarios. Figures I-2 through I-5 show sample timelines for typical servicing missions on attached and free flyer payloads, respectively. The numbers shown are those assigned to the appropriate OSAs. (Note that SIA in Figure I-3 stands for "Station Interface Adapter", a means of connecting attached payloads to the SS.)

To further illustrate this technique of describing typical strawmen, consider the case of the Hubble Space Telescope (HST). This free-flyer requires only one type of servicing (denoted Type A for HST), which has as its "principal" activity the change-out of science instruments and spacecraft subsystem modules. The complete servicing scenario for HST is defined as the aggregation of nine of the possible 14 servicing activities. The nine activities fall into preparatory, principal, and close-out servicing categories as follows:

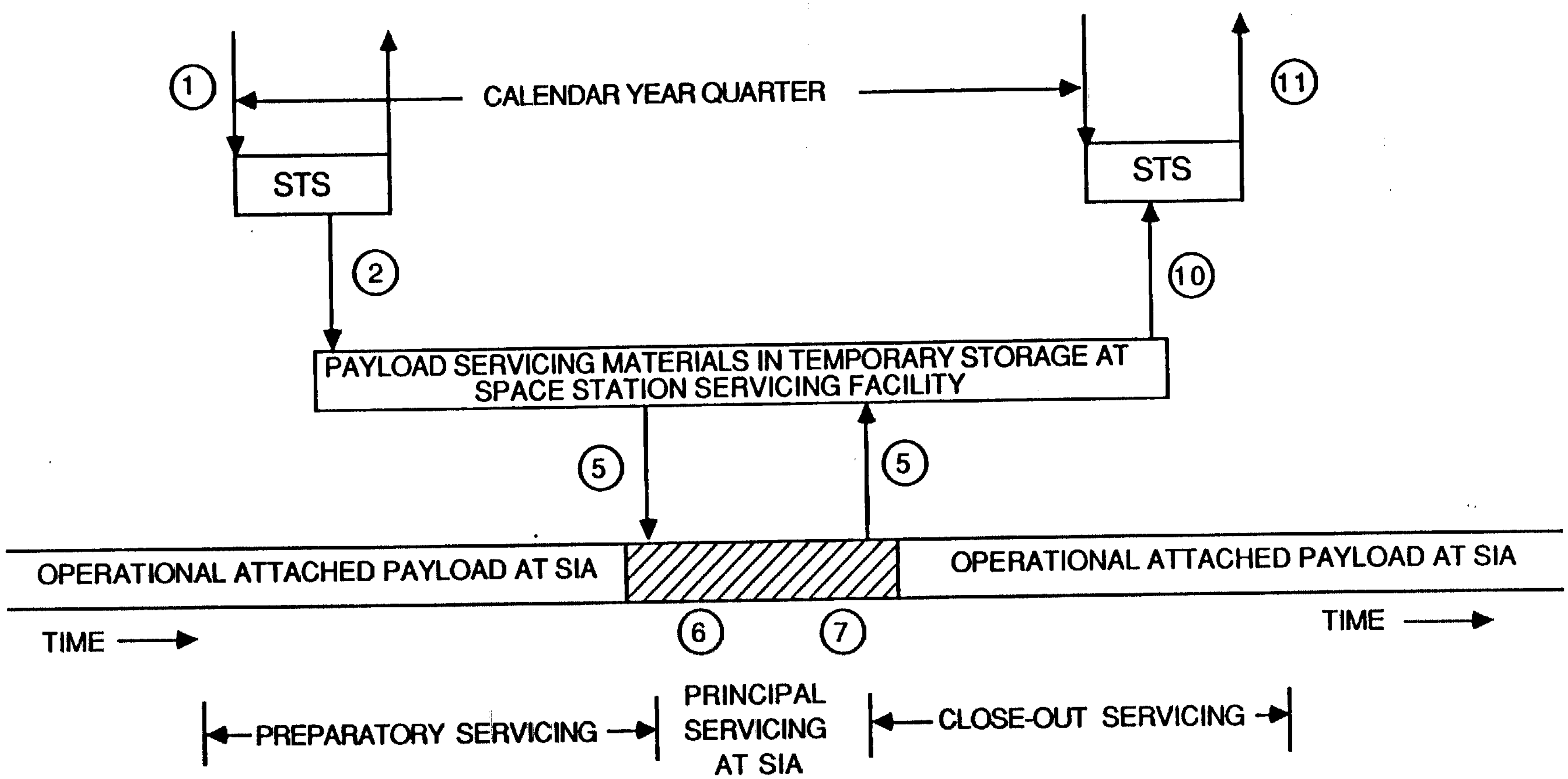
HST Preparatory Servicing

Activity 1: STS Brings Servicing Materials From Earth to Space Station. The parameters mass and volume up, and mass and volume stored on SS are specified or estimated.

Activity 2: Servicing Materials Are Unloaded From STS Orbiter Bay to SS Servicing Facility. Elapsed, SS Crew IVA and EVA, and robotics servicing times are specified or estimated.

Activity 3: OMV Brings HST From Orbit to SS Servicing Facility. Number OMV flights (one), purpose (payload retrieval), and date (CY Quarter) are specified.

Activity 4: HST Berthing-Related Activities Take Place at SS. Servicing times are estimated, as in Activity 2.

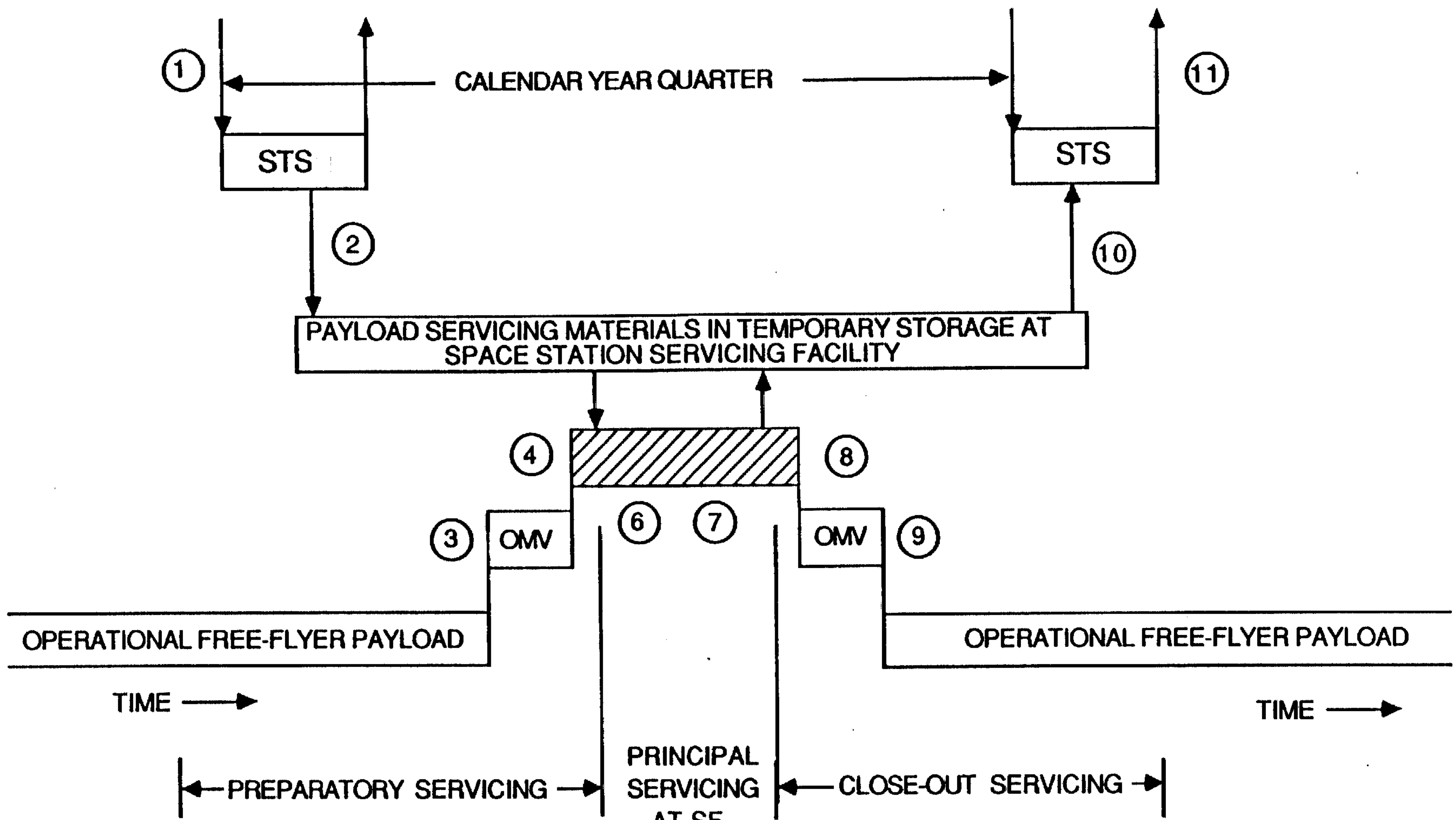


SERVICING ACTIVITIES

1. STS BRINGS SERVICING MATERIALS FROM EARTH TO SS
2. ROBOTIC UNLOADING OF MATERIALS FROM STS TO SS SF
5. MRMS/MSC TRANSPORTS MATERIALS TO SIA AND BACK
6. PAYLOAD ORU CHANGEOUT AT SIA
7. PAYLOAD CONSUMABLES REPLENISHMENT AT SIA
10. ROBOTIC LOADING OF MATERIALS INTO STS
11. STS TAKES SERVICING MATERIALS TO EARTH

FIGURE I-3.

TYPICAL SERVICING MISSION TIMELINE FOR SS ATTACHED PAYLOAD: PRINCIPAL SERVICING AT SIA

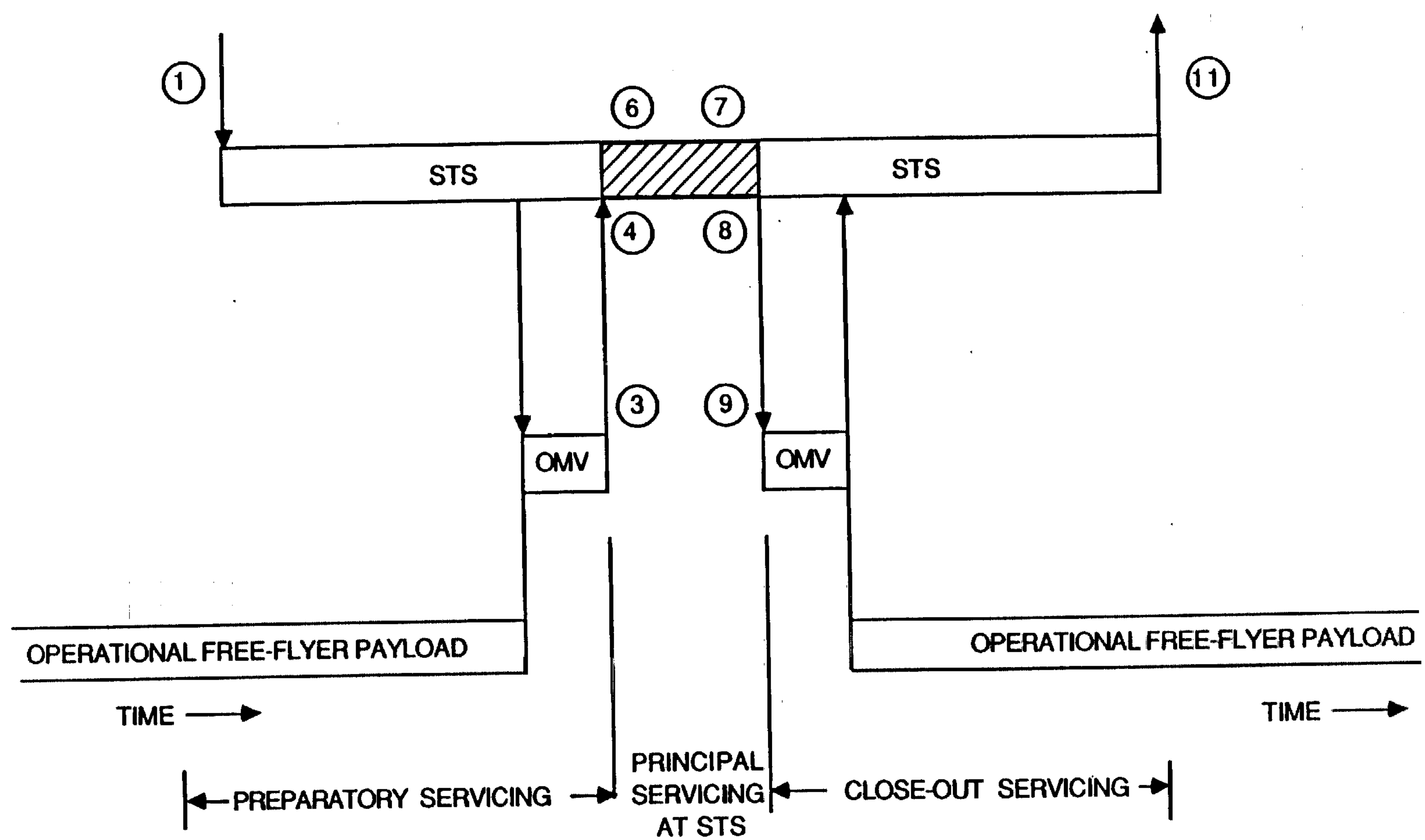


SERVICING ACTIVITIES

1. STS BRINGS SERVICING MATERIALS FROM EARTH TO SS
2. ROBOTIC UNLOADING OF MATERIALS FROM STS TO SS SF
3. OMV BRINGS PAYLOAD FROM ORBIT TO SS SF
4. PAYLOAD BERTHING-RELATED ACTIVITIES AT SS
6. PAYLOAD ORU CHANGEOUT AT SS SF
7. PAYLOAD CONSUMABLES REPLENISHMENT AT SS SF
8. PAYLOAD DEBERTHING-RELATED ACTIVITIES
9. OMV DEPLOYS PAYLOAD FROM SS SF
10. ROBOTIC LOADING OF MATERIALS INTO STS
11. STS TAKES SERVICING MATERIALS TO EARTH

FIGURE I-4.

TYPICAL SERVICING MISSION TIMELINE FOR FREE-FLYER PAYLOAD: PRINCIPAL SERVICING AT SS



SERVICING ACTIVITIES

(1) STS BRINGS SERVICING MATERIALS FROM EARTH TO SERVICING ORBIT

(3) OMV BRINGS PAYLOAD FROM ORBIT TO STS *

(4) PAYLOAD BERTHING-RELATED ACTIVITIES AT STS

(6) PAYLOAD ORU CHANGEOUT AT STS

(7) PAYLOAD CONSUMABLES REPLENISHMENT AT STS

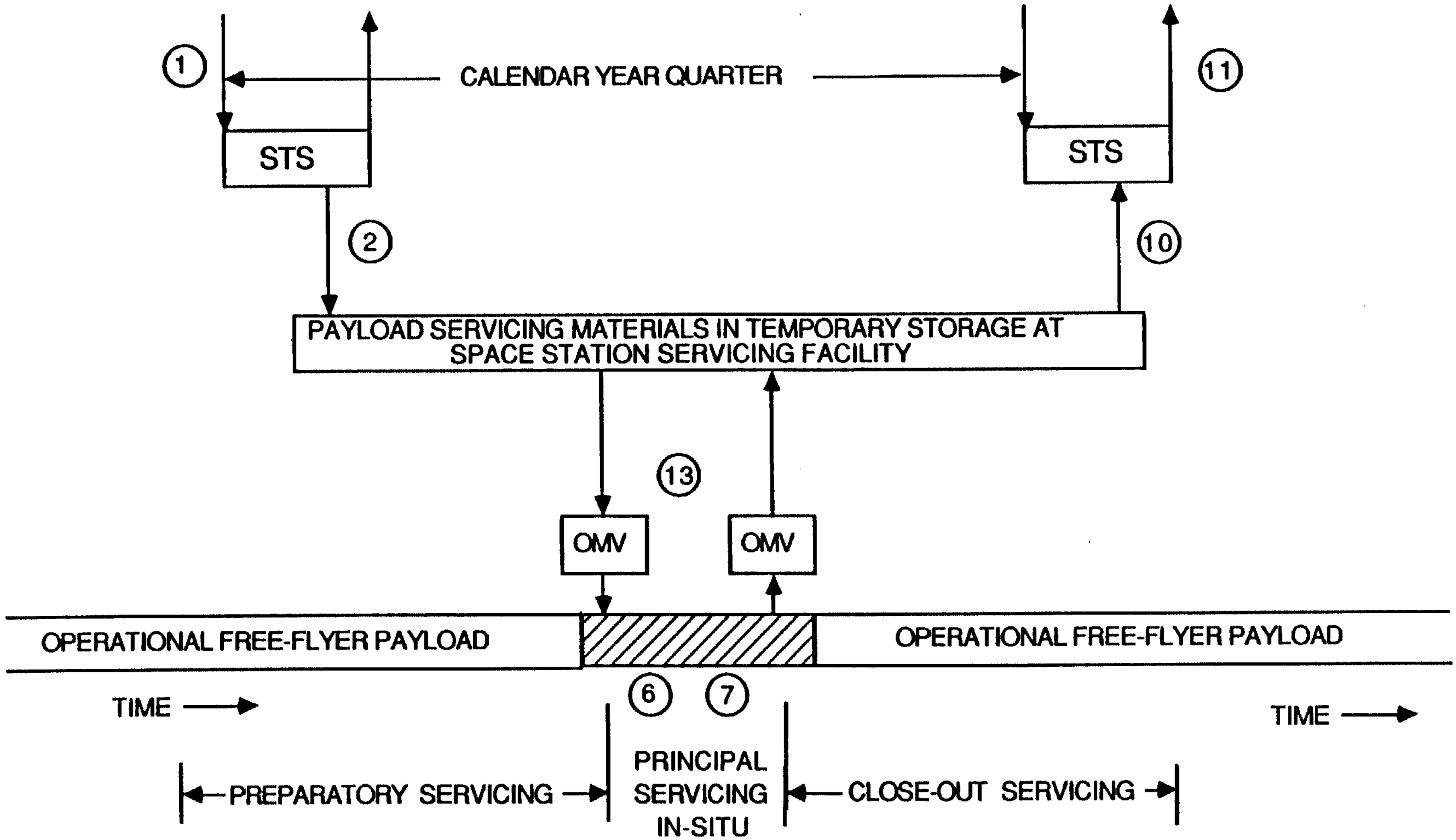
(8) PAYLOAD DEBERTHING-RELATED ACTIVITIES AT STS

(9) OMV DEPLOYS PAYLOAD FROM STS *

(11) STS TAKES SERVICING MATERIALS TO EARTH

NOTE: PAYLOAD RETRIEVAL AND DEPLOYMENT MAY IN SOME CASES BE EFFECTED WITHOUT REQUIREMENTS FOR OMV SUPPORT

FIGURE I-5.
TYPICAL SERVICING MISSION TIMELINE FOR FREE-FLYER PAYLOAD: PRINCIPAL SERVICING AT STS



SERVICING ACTIVITIES

1. STS BRINGS SERVICING MATERIALS FROM EARTH TO SS
2. ROBOTIC UNLOADING OF MATERIALS FROM STS TO SS SF
6. PAYLOAD ORU CHANGEOUT IN-SITU
7. PAYLOAD CONSUMABLES REPLENISHMENT IN-SITU
10. ROBOTIC LOADING OF MATERIALS INTO STS
11. STS TAKES SERVICING MATERIALS TO EARTH
13. LOADING/UNLOADING OF OMV FROM/TO SS PRIOR TO AND FOLLOWING IN-SITU SERVICING

FIGURE I-6.

TYPICAL SERVICING MISSION TIMELINE FOR FREE-FLYER PAYLOAD: PRINCIPAL SERVICING IN-SITU

HST Principal Servicing

Activity 6: Science Instrument and Subsystem Modules Are Changed-Out. Servicing times are estimated.

HST Close-Out Servicing

Activity 8: HST Deberthing-Related Activities at SS. Servicing times are estimated.

Activity 9: OMV Deploys HST from SS to Orbit. Number of flights (one), major purpose (payload deployment), and date (CY Quarter) are specified.

Activity 10: Servicing Materials Are Loaded From SS Into STS Orbiter Bay. Servicing times are estimated.

Activity 11: STS Takes Residual Payload Servicing Materials to Earth. Mass and volume of servicing materials going down are estimated.

Note that the following servicing activities are not included since they are not required, or are not applicable to HST:

Activity 5: Transport Servicing Materials From SS Servicing Facility to Payload and Back Using MRMS Robot. (Applies only to SS attached external payloads.)

Activity 7: Replenish Consumables. (HST does not require consumable replenishment for first generation science instruments.)

Activity 12: Rack Changeout of Pressurized Module Payload. (Applies only to Payload in pressurized SS module.)

Activity 13: Special Case, In-Situ Servicing. (Does not apply to HST which is serviced at SS.)

Activity 14: On Orbit Payload Assembly. (Not required. HST is launched and serviced in assembled configuration.)

3. Derivation of Algorithms

For many payloads currently in the planning stage, servicing estimates have not yet been developed by the Payload Offices or the Space Station Program. In order to establish requirements for these payloads, a set of orbital servicing activites was created to describe the strawman missions, and equations were developed to estimate the major parameters associated with each activity.

In the Book I appendices, crew times were estimated for "generic servicing scenarios" associated with free-flying and attached payloads. A bottom-up process was used in which a generic scenario (such as "unload and store OSUs and flight support equipment") was subdivided into detailed activities (such as "2 EVA crew egress and translate to STS"), and parameters for the scenario were obtained by summing the parameters for each of its component activities. In Book II, these generic scenarios have been replaced by orbital servicing activites, and the associated parameters have been estimated not by the detailed bottom-up process, but through simple equations based on servicing test data, facility design values, and payload similarities. It is expected that this new approach will have broader applicability and provide more rapid and accurate estimations. A detailed discussion of the algorithms is presented in Appendix C.

As a general rule, servicing estimates made using these estimating algorithms are replaced by payload office estimates when such values are available.

4. Derivation of Payload Servicing Data Sheet

A payload data sheet (included as Appendix D) was prepared by BDM during the data gathering process to describe how each of the 14 OSAs applies to a particular payload, to assist payload engineers in describing payload strawmen in terms of OSAs, and to facilitate collection and calculation of relevant parameters. The equations described in Appendix C were used in this data sheet to guide the payload engineers in producing consistent estimates.

5. Data Collection

Using a preliminary model based on the OSAs, and with the new information format as a guideline, technical discussions were conducted with payload mission planners at NASA/Headquarters and NASA/GSFC. Telephonic or written communications were conducted with other NASA centers and in some cases with designated NASA contractors. Available documents for each project were also reviewed.

6. Data Presentation/Approval

Payload descriptions were compiled in the payload information format described in Section H.1 above. The completed payload units are presented in alphabetical order as Chapter 3 of this report. In all cases a draft of the payload unit was submitted to payload office representatives for review and approval before final publication.

I. ASSUMPTIONS/CONSTRAINTS

The following assumptions and constraints apply to this version of the Data Book:

(1) On-orbit servicing is defined above in Section C, with additional elaboration in Sections D and E. Payload servicing missions are constructed to consist of one or more of the servicing activities listed in Table I-1.

(2) Only OSSA Missions which are candidates for flights under the SS Program are considered.

(3) No analysis has been performed to evaluate the compatibility of payload requirements and SS Program servicing capabilities. Also, no attempt has been made to schedule servicing to regulate the "workload" on the Program.

(4) The earliest time that an SS attached payload can be operational is considered (as of this writing) to be 3rd quarter of 1994. As a consequence, attached payloads treated in this study show initial operating dates which are no earlier than 3rd quarter 1994.

(5) STS payload servicing flights which are expected to occur before the Space Station is operational are not included. For example, the first servicings of HST and the Explorer Platform are not part of the database presented in this report.

(6) It is assumed that most payload servicing activities carried out during the period of interest (1994 through 2005) will use, as in the past, a mixture of manned efforts (including IVA and EVA) and robotic operations.

(7) It is assumed that during extravehicular activity (EVA) two astronauts work together outside the SS or STS and a third astronaut performs intravehicular activity (IVA) to provide full time monitoring of the EVA. Thus 1 IVA crew-hour is included for every 2 EVA crew-hours.

(8) BDM estimates of EVA time are based on the airlock egress to airlock ingress period and do not include time for preparatory activities such as equipment checkout and prebreathing actions.

(9) "Robotic Time" as presented in this report encompasses the use of astronaut-directed equipment such as manipulators (e.g., the MRMS) and transport systems (e.g., the MSC). Whenever "robotic time" is called for, an equal period of IVA time is specified to control the activity.

(10) It is assumed that the Space Station Program will supply certain payload consumables, specifically hydrazine, helium, and water. These requirements are specified and servicing times are estimated.

(11) When in-situ servicing is needed for a free-flyer, servicing times are considered to be TBD since insufficient data is available on the telerobotic procedures.

(12) The BDM estimating equations are derived and extrapolated using limited servicing data. The results of the calculations must be viewed as top-level approximations. Nevertheless these equations and methods serve as a paradigm for future servicing data collection and model refinement.

(13) Throughout the report, numbers generated by BDM estimates are indicated by a carat symbol immediately following the number, or by an appropriate footnote.

(14) Some payloads are still in definition or study phases, and cannot be quantified with regard to most or all servicing requirements and interfaces.

J. ORGANIZATION OF THE REPORT

This book is organized into three chapters and four appendices.

Chapter I: Introduction provides an overview of the effort, including discussions of objectives, background, procedures, and a description of payload categories. It also defines servicing, OSUs, and OSAs. It lists all payloads and collects major assumptions and constraints in one place for reference.

Chapter II: Top Level Servicing Requirements contains a summary of the servicing requirements derived from the individuals payloads.

Chapter III: Top Level Requirements Database describes the actual servicing data for each of the 31 payloads studied and constitutes the bulk of the report. Each payload servicing description contains 15 sections. The first two sections of these units identify payload points-of-contact, science objectives, and overall launch and servicing schedules. They also provide a brief physical description of the payload.

Sections 3 through 7 provide detailed information on the on-orbit servicing characteristics of the payload including discussion of general serviceability, safety considerations, interfaces (with SS and STS, for example), environmental considerations, and servicing accommodations such as access, modularity, and automation.

Section 8 provides a Servicing Materials Check List which identifies the need for servicing equipment, consumables, and appropriate carriers, and indicates whether these items should be provided by the Space Station Program or by the OSSA Payload Office.

Section 9 through 12 provide more detailed information on the ORUs, flight support equipment (FSE), consumables and containers, and the carriers which may be needed to bring these servicing materials to and from orbit.

Section 13 presents time estimates (elapsed time, IVA time, EVA time, robotics time) associated with various servicing activities ranging from loading/unloading servicing materials from/into the STS Orbiter, berthing/deberthing free-flyers, moving materials on the Space Station, changing out payload OSUs, and replenishing payload consumables.

In Section 14, typical or "strawman" servicing scenarios are defined and discussed, and corresponding requirements are presented for up/down servicing material mass/volume, SS storage, servicing times, and OMV (OTV) support for free-flyers.

In Section 15, a Payload Program Milestone and Servicing Schedule is provided and corresponding total estimated payload servicing requirements are presented through CY2005.

A more detailed description of all these sections may be found in Appendix B.

<u>Appendix A</u> contains definitions of abbreviations and acronyms.

<u>Appendix B</u> describes the contents of each section of the Payload Information Format.

<u>Appendix C</u> is a description and discussion of BDM algorithms for on-orbit payload servicing.

<u>Appendix D</u> is a sample Payload Data Sheet of the type employed to collect and calculate parametric information on payload strawmen servicing missions.

<u>Appendix E</u> contains abbreviated payload information in the form of tabular and graphical summaries of key quantities and derived values.

CHAPTER II
TOP LEVEL SERVICING REQUIREMENTS

A. INTRODUCTION

This chapter presents a summary of the on-orbit servicing requirements derived from the individual payloads of the OSSA payload set. The payload database in Chapter III contains additional servicing information from which lower level servicing requirements can be generated as the need arises.

The level of detail contained in this report reflects the level of development of the payloads analyzed. It is expected that both payload mission specific engineering details and derived on-orbit servicing requirements will need to be updated and expanded as development activities continue.

It should also be emphasized that this report is a working document intended to supply additional detail on servicing OSSA missions under the Space Station Program. Formal requirements derived from this report and other sources are under configuration control by OSSA and are submitted to the Space Station Program through the Mission Requirements Data Base (MRDB).

B. RESULTS OF SUMMARY REQUIREMENTS ANALYSES

1. Summary of Payload Servicing Requirements

Payload servicing requirements are presented in twelve requirement categories developed in consultation with OSSA. The requirement categories are intended to provide a sufficiently comprehensive set of specifications to support preliminary Space Station design and planning for on-orbit servicing.

The twelve categories (with brief definitions) are as follows:

(1) Volume

This category includes:

- The payload operational, servicing, and storage envelopes
- The pressurized and unpressurized Space Station storage volumes required for payload servicing materials
- STS servicing materials volume up
- STS servicing materials volume down

Note that "servicing materials" include: Scientific Instruments (SIs), Orbital Replacement Units (ORUs), Flight Support Equipment (FSE), consumables, servicing materials carriers and tanks, and any miscellaneous equipment not falling into these categories but identified for servicing by the Program and/or Project Offices.

(2) Mass

The mass category includes the following items:

- Total operational payload mass
- The pressurized and unpressurized Space Station storage masses required by payload servicing materials
- STS servicing materials mass up
- STS servicing materials mass down

(3) Power

This category includes:

- The payload operational and servicing power
- The power required to condition servicing materials during storage

(4) Servicing Schedule

In this category three data items are defined:

- Calendar year of the first SS-related payload servicing
- Interval between servicings
- Expected payload operational lifetime

(5) OMV Flights

This category consists of two elements:

- Retrieval/deployment flights
- In-situ servicing flights

Each flight consists of one round trip from the Space Station. The OMV will be capable of providing a wide variety of services including payload deployment (delivery), retrieval, reboost, deboost (to re-entry), viewing, and contingency return. The OMV will also be capable, when equipped with a telerobotic servicer, of servicing a free-flyer payload "in-situ", i.e., at the location of the free-flyer, remote from either the SS or the STS.

For the purposes of this data book it was considered sufficient to specify when OMV support was required (by calendar year and quarter), and the purpose of the support (generally payload retrieval, deployment, or in-situ servicing).

A more detailed treatment of the interfaces between candidate OSSA free-flyers and the OMV is contained in A Study of the Requirements of OSSA Free-Flyer Payloads for Support by the Orbital Maneuvering Vehicle, Volume I (April 1987) and Volume II (June 1987), The BDM Corporation.

(6) Servicing Times

This category includes elapsed time, EVA crew hours, IVA crew hours, and robotic time. Note that at least two crew members are required simultaneously to perform an EVA. Robotic time refers to astronaut-directed mechanized activity (e.g., transport of servicing materials to the location of an SS-attached payload using the MSC).

(7) Mechanical Interfaces

This category includes the mechanical interfaces (if any) needed by the payload during servicing. Examples of required interfaces include OMV, FSS, trunnions, pallets, and the Space Station Remote Manipulator System (SSRMS).

(8) SS Program-Provided Consumables

In this category consumables provided to the payload by the Space Station are identified. Such consumables include (but are not limited to) hydrazine, heluim, and water.

(9) Thermal

This category refers to the temperature limits required for the following:

- payload servicing material storage
- payload servicing
- ORU handling

(10) Pointing Precautions

This category encompasses pointing precautions needed to prevent damaging exposure to intense light, loss of thermal control, velocity vector avoidance, etc.

(11) Contamination

This category refers to concerns such as molecular/particulate contamination and outgassing.

(12) Other

This category contains miscellaneous servicing requirements, including radiation and EMI/EMC concerns, identification of in-situ servicing, and other needs not previously covered in the above categories.

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Table II-1. SUMMARY OF PAYLOAD IN
FOR SPACE STATION AT

	PAYLO			
REQUIREMENT	ASTRO	ASTROMAG	ATF	CDCE
VOLUME (m^3)				
P/L Operational Envelope	270.0	80.0	152.0	9.0
P/L Servicing Envelope	N / A	80.0	152.0	9.0
P/L Storage Envelope	N / A	80.0	205.0	2.0
Servicing Materials Pressurized Storage	0.0	0.0	0.5	0.0
Servicing Materials Unpressurized Storage	0.0	41.0	8.0	1.0
STS Servicing Materials Volume Up	0.0	41.0	8.5	1.0
STS Servicing Materials Volume Down	0.0	41.0	8.5	1.0
MASS (kg)				
P/L Operational Mass	5700.0	5000.0	5145.0	350.0
Servicing Materials Pressurized Storage	0.0	0.0	100.0	0.0
Servicing Materials Unpressurized Storage	0.0	2355.0	750.0	40.0
STS Servicing Materials Mass Up	0.0	2355.0	850.0	40.0
STS Servicing Materials Mass Down	0.0	2355.0	850.0	40.0
POWER (kW)				
P/L Operation	5.0	2.0	1.4	0.3
P/L Servicing	N / A	0.5	TBD	TBD
Servicing Materials Storage	N / A	0.5	TBD	TBD
SERVICE SCHEDULE				
First SS - Related Service (Year)	N / A	1996	1996	1995
Service Interval (Months)	N / A	12	60	6
Operational Lifetime (Years)	1	10	20	5
OMV FLIGHTS				
P/L Retrieval / Deployment	0	0	0	0
IN - SITU Servicing	0	0	0	0
SERVICING TIMES (HRs)				
Elasped Time	0	TBD	8	4
IVA Crew Hours	0	TBD	14	4
EVA Crew Hours	0	TBD	15	8
Robotics Time	0	TBD	6	3
MECHANICAL INTERFACES	TBD	TBD	SSRMS Trunnions	TBD
SS - PROGRAM PROVIDED CONSUMABLES	None	Superfluid Helium	None	None
THERMAL				
P/L Servicing Materials Storage	N / A	0°-30°C		
P/L Servicing	N / A	0°-30°C	TBD	TBD
ORU Handling	N / A	TBD		
POINTING PRECAUTIONS	N / A	None	None (when aperture doors are closed)	TBD
CONTAMINATION CONCERNS	Precautions Required	None	Precautions Required	Precautions Required
OTHER CONSTRAINTS	None	None	None	EM Radiation

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*NOTE: Requirements shown in this table are preliminary estimates a

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IVIDUAL SERVICING REQUIREMENTS
ACHED PAYLOADS*

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CRNE	HH / ERBE	HRSO	LAMAR	LASERCOM	LAWS
50 N / A N / A N / A N / A N / A N / A	10 N / A N / A N / A N / A N / A N / A	31.4 31.4 31.4 0.0 3.2 3.2 3.2	25.2 25.2 25.2 0.0 8.0 8.0 8.0	0.1 N / A N / A N / A N / A N / A N / A	52.0 52.0 12.5 0.0 0.4 0.4 0.4
2520.0 N / A N / A N / A N / A	1080.0 N / A N / A N / A N / A	2234.0 0.0 535.0 535.0 535.0	6818.0 0.0 2405.0 2405.0 1682.0	25.0 N / A N / A N / A N / A	800.0 0.0 620.0 620.0 620.0
0.4 N / A N / A	0.1 N / A N / A	0.8 TBD TBD	TBD	TBD N / A N / A	3.0 0.4 TBD
N / A N / A 2	N / A N / A 10	TBD 12 3	TBD 36 TBD	N / A N / A 1	2001 36 5
0 0	0 0	0 0	0 0	0 0	0 0
N / A	N / A	7 9 12 6	20 31 39 12	N / A	7 12 13 6
Trunnions	TBD	TBD	TBD	TBD	TBD
None	None	None	None	None	None
-10° -40° N / A N / A	TBD	TBD	TBD	TBD	TBD
None	None	TBD	TBD	TBD	TBD
None	Precautions Required	Precautions Required	TBD	Precautions Required	Precautions Required
SAA Concerns	EM Radiation	TBD	TBD	TBD	TBD

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Table II-1. SUMMARY OF PAYLOA
FOR SPACE STATION

	PAYLOAD			
REQUIREMENT	**PIMS**	**POF**	**SBAR**	**SRI**
VOLUME (m^3)				
P/L Operational Envelope	0.5	465.0	110.0	
P/L Servicing Envelope	N/A	465.0	110.0	
P/L Storage Envelope	N/A	120.0	42.0	TBD
Servicing Materials Pressurized Storage	N/A	0.0	0.3	
Servicing Materials Unpressurized Storage	N/A	3.0	19.0	
STS Servicing Materials Volume Up	N/A	3.0	15.0	
STS Servicing Materials Volume Down	N/A	3.0	15.0	
MASS (kg)				
P/L Operational Mass	100.0	2700.0	3075.0	
Servicing Materials Pressurized Storage	N/A	0.0	30.0	
Servicing Materials Unpressurized Storage	N/A	300.0	2685.0	TBD
STS Servicing Materials Mass Up	N/A	300.0	1920.0	
STS Servicing Materials Mass Down	N/A	300.0	1920.0	
POWER (kW)				
P/L Operation	0.1	0.8	0.7	TBD
P/L Servicing	N/A	0.8	TBD	
Servicing Materials Storage	N/A	0.8	0.3	
SERVICE SCHEDULE				
First SS-Related Service (Year)	N/A	1999	1997	TBD
Service Interval (Months)	N/A	60	6	
Operational Lifetime (Years)	5	15	15	
OMV FLIGHTS				
P/L Retrieval / Deployment	0	0	2	TBD
IN-SITU Servicing	0	0	0	
SERVICING TIMES (HRs)				
Elasped Time	N/A	5	23	
IVA Crew Hours		8	28	TBD
EVA Crew Hours		7	28	
Robotics Time		4	11	
MECHANICAL INTERFACES	TBD	TBD	SSRMS, Trunnions, OMV	TBD
SS-PROGRAM PROVIDED CONSUMABLES	None	None	Hydrazine	TBD
THERMAL				
P/L Servicing Materials Storage	TBD	Servicing Dependent	7°-50°C	TBD
P/L Servicing			7°-50°C	
ORU Handling			ORU-dependent	
POINTING PRECAUTIONS	None	TBD	Precautions Required	TBD
CONTAMINATION CONCERNS	None	Class 10000 Clean Room Environment	TBD	TBD
OTHER CONSTRAINTS	TBD	TBD	EM Radiation	TBD

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*NOTE: Requirements shown in this table are preliminary estimates and are presented for p

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INDIVIDUAL SERVICING REQUIREMENTS
ATTACHED PAYLOADS* (CONTINUED)

STO/PIG	STO/SIG	STO/SS	TRIS	TRMM
TBD	TBD	TBD	1.1	7.0
TBD	TBD	TBD	1.1	N/A
TBD	TBD	TBD	1.1	N/A
0.0	0.0	0.0	0.0	N/A
0.7	2.3	4.2	0.7	N/A
0.7	1.1	4.2	0.7	N/A
0.7	1.1	4.2	0.7	N/A
TBD	TBD	7943.0	360.0	596.0
0.0	0.0	0.0	0.0	N/A
131.0	427.0	816.0	157.0	N/A
133.0	202.0	816.0	157.0	N/A
131.0	201.0	809.0	157.0	N/A
		6.7	0.7	0.5
TBD	TBD	TBD	TBD	N/A
		TBD	TBD	N/A
1994	1994	1994	1998	N/A
3	3	3	36	N/A
4	4	4	TBD	3
2	0	2	0	0
0	0	0	0	0
17	12	30	5	N/A
17	23	30	9	
TBD	TBD	TBD	9	
13	12	26	5	
SSRMS, APAE	SSRMS, APAE	SSRMS, Trunnions, APAE	TBD	PIA, SIA
None	None	None	None	None
TBD	TBD	TBD	TBD	TBD
		TBD		
		ORU - dependent		
None	None	None	None	None
Precautions Required	Precautions Required	Precautions Required	Precautions Required	TBD
AA Constraints	SAA Constraints	SAA Concerns	TBD	TBD

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Table II-2. SUMMARY OF PAYLOAD IN
FOR FREE-FLYERS AND C

	P		
REQUIREMENT	**AXAF**	**EP**	**GRO**
VOLUME (m^3)			
P/L Operational Envelope	3039.0	152.0	1850.0
P/L Servicing Envelope	345.0	31.0	150.0
P/L Storage Envelope	345.0	31.0	150.0
Servicing Materials Pressurized Storage	0.0	0.0	0.0
Servicing Materials Unpressurized Storage	66.0	7.4	0.0
STS Servicing Material Volume Up	66.0	7.4	0.0
STS Servicing Material Volume Down	66.0	7.4	0.0
MASS (kg)			
P/L Operational Mass	13500.0	2963.0	15790.0
Servicing Materials Pressurized Storage	0.0	0.0	0.0
Servicing Materials Unpressurized Storage	1720.0	1382.0	0.0
STS Servicing Material Mass Up	1720.0	1382.0	0.0
STS Servicing Material Mass Down	1720.0	1382.0	0.0
POWER (kW)			
P/L Operation	2.8	0.7	1.7
P/L Servicing	0.6	0.3	TBD
Servicing Materials Storage	0.6	0.3	N/A
SERVICE SCHEDULE			
First SS - Related Service (Year)	1998	1995	1994
Service Interval (Months)	36	24	48
Operational Lifetime (Years)	15	10	8
OMV FLIGHTS			
P/L Retrieval / Deployment	2	2	2
IN - SITU Servicing	0	0	0
SERVICING TIMES (HRs)			
Elasped Time	20	28	15
IVA Crew Hours	20	28	15
EVA Crew Hours	25	0	18
Robotics Time	10	15	5
MECHANICAL INTERFACES	SSRMS, Trunnions, FSS, OMV	SSRMS, Trunnions, FSS	SSRMS, Trunnions, FSS, OMV
SS - PROGRAM PROVIDED CONSUMABLES	Superfluid Helium	None (Payload Dependent)	Hydrazine
THERMAL			
P/L Servicing Material Storage	-10°-40°C	-15°-50°C	Passive Control
P/L Servicing	0°-40°C	-15°-50°C	Passive Control
ORU Handling	ORU - Dependent	ORU - Dependent	TBD
POINTING PRECAUTIONS	Precautions Required	Precautions Required	None
CONTAMINATION CONCERNS	Class 100 Clean Room	TBD	Precautions Required
OTHER CONSTRAINTS	Outgassing and SAA Constraints	TBD	None Specified

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*NOTE:- Requirements shown in this table are preliminary estimate

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IVIDUAL SERVICING REQUIREMENTS
-ORBITING PLATFORMS*

YLOAD				
HST	LDR	SIRTF	3S	XGP
2500.0 2500.0 190.0 0.0 66.0 66.0 66.0	15000.0 15000.0 300.0 0.0 8.0 8.0 8.0	2960.0 145.3 145.3 0.0 11.6 11.6 11.6	110.0 110.0 42.0 0.0 19.0 15.0 15.0	125000.0 125000.0 230.0 0.0 1.2 1.2 1.2
11600.0 0.0 1865.0 1865.0 1865.0	30000.0 0.0 840.0 840.0 840.0	6300.0 0.0 845.0 845.0 845.0	2962.0 0.0 2582.0 1791.0 1791.0	10000.0 0.0 1400.0 1400.0 400.0
2.1 1.7 0.7	7.0 TBD TBD	1.7 0.4 0.0	0.7 TBD 0.3	1.0 1.0 TBD
1998 22 15	2000 24 15	1998 27 10	1996 6 10	1998 36 20
2 0	1 0	2 0	2 0	1 (W / OTV) 1 (W / OTV)
23 23 34 16	131 131 225 57	34 34 22 13	19 22 23 9	2 2 0 2
RMS, Trunnions, FSS, OMV	SSRMS OMV	SSRMS, Trunnions, FSS, OMV	SSRMS, Trunnions, OMV	TBD
None	Superfluid Helium	Superfluid Helium	Hydrazine	Possibly Hydrazine
20°-50°C 20°-50°C RU - Dependent	TBD TBD TBD	-23° to +27°C -23° to +27°C -23° to +27°C	7°-50°C 7°-50°C ORU - Dependent	TBD
Precautions Required	Precautions Required	Precautions Required	Precautions Required	None Specified
Class 100 Clean Room	Precautions Required	Class 1000 Clean Room	Instrument Dependent	None Specified
SAA and EM Radiation	None	Ionizing Radiation	EM Radiation	TBD

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Table II-3. SUMMARY OF PAYL
FOR LABORATORY

	SCIENCE LA
REQUIREMENT	LSRF
VOLUME (m³)	
P/L Operational Envelope	70.0
P/L Servicing Envelope	70.0
P/L Storage Envelope	70.0
Servicing Materials Pressurized Storage	3.3
Servicing Materials Unpressurized Storage	18.8
STS Servicing Materials Volume Up	22.1
STS Servicing Materials Volume Down	22.3
MASS (kg)	
P/L Operational Mass	11650.0
Servicing Materials Pressurized Storage	1053.0
Servicing Materials Unpressurized Storage	7213.0
STS Servicing Materials Mass Up	8266.0
STS Servicing Materials Mass Down	7999.0
POWER (kW)	
P/L Operation	9.5
P/L Servicing	<9.5
Servicing Materials Storage	<9.5
SERVICE SCHEDULE	
First SS - Related Service (Year)	1995
Service Interval (Months)	3
Operational Lifetime (Years)	30
OMV FLIGHTS	
P/L Retrieval / Deployment	0
IN - SITU Servicing	0
SERVICING TIMES (HRs)	
Elasped Time	TBD
IVA Crew Hours	TBD
EVA Crew Hours	TBD
Robotics Time	TBD
MECHANICAL INTERFACES	SS Pressurized
SS - PROGRAM PROVIDED CONSUMABLES	TBD
THERMAL	Module Environm
P/L Servicing Materials Storage	
P/L Servicing	
ORU Handling	
POINTING PRECAUTIONS	N / A
CONTAMINATION CONCERNS	Bio Mater Hazardous Re etc.
OTHER CONSTRAINTS	Logistics Mod Support Cap Maneuverabl Airlock S

*NOTE: Req

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AD INDIVIDUAL SERVICING REQUIREMENTS
ODULES AND POLAR PLATFORMS.

ORATORY MODULE		POLAR PLATFORM	
	MMPF	EOS	STO/POP (A/B)
	45.0 45.0 45.0 11.0 130.0 140.0 50.0	TBD TBD TBD N/A N/A 65.0 65.0	TBD
	9000.0 2400.0 2600.0 5000.0 3800.0	12380.0 N/A N/A 6800.0 3400.0	TBD
	28.0 TBD TBD	6130.0 1120.0 TBD	TBD
	1995 1 30	1998 36 15	1995 12 4
	0 0	TBD	0 1
	TBD TBD TBD TBD	TBD TBD TBD TBD	TBD
dule	SS Pressurized Module	STSRMS, FTS	SSRMS, OMV, FTS
	TBD	Propellants	Propellants
	Module Environment	N/A N/A ORU - Dependent	TBD
	N/A	Radiator FOV's	None Specified
ents,	Class 100000 Clean Room	Precautions Required	Precautions Required
Life lity lack	Radiation Monitoring	Serviced by STS/OMV/FTS	Serviced by STS/OMV/FTS

rements shown in this table are preliminary estimates and are presented for planning purposes only.

The top level mission requirements are summarized in Tables II-1, II-2, and II-3. For each of the 31 payloads analyzed, information extracted from the corresponding payload write-up in the database of Chapter III was placed into the twelve categories described above. For payloads having more than one servicing strawman scenario, a composite set of data was selected to best represent the payload's requirements for each resource category. The "TBD" items displayed in the tables reflect the fact that the payload is either in its conceptual or early design phase, or that servicing concepts have not yet been addressed to a level of detail sufficient to support requirements definition or estimation. In addition, because the extensive detail contained in the Chapter III database resists easy summary in the format of Tables II-1 through II-3, this summary information is of necessity only representative. Chapter III should be consulted for details appropriate to each payload.

2. Servicing Missions by Calendar Year Quarter

Table II-4 illustrates the on-orbit servicing missions by calendar year quarter for the 31 candidate OSSA payloads. Since the launch dates are subject to change as NASA's plans evolve, and since the servicing opportunities are, in general, physically or programmatically linked to these dates, the servicing missions shown must be considered as only representative of the OSSA programs.

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TABLE II-4. ON-ORBIT SERVICING
BY C

PAYLOAD	1994				1995				1996				1997				1998				1	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
SS-ATTACHED																						
ASTRO																						
ASTROMAG									X						X						X	
ATF												X										
CDCE					X		X		X		X		X		X		X		X		X	
CRNE																				*NO SER*		
HH/ERBE																				*NO SER*		
HRSO																				*SERVICI*		
LAMAR																				*SERVICI*		
LASERCOM																				*NO SER*		
LAWS																						
LSRF					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MMPF					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PIMS																				*NO SER*		
POF																						
SBAR														X		X		X		X		X
SRI																				*SERVICI*		
STO/PIG				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
STO/SIG				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
STO/SS				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
TRIS																	X					
TRMM																				*NO SER*		
LOW INCLINATION ORBIT FREE FLYERS																						
AXAF																				X		
EP					X								X								X	
GRO	X																					
HST																			X			
LDR																						
SIRTF																		X				
3S										X	X	X	X	X	X	X	X	X	X	X	X	X
XGP																				X		
POLAR ORBIT FREE FLYERS																						
Eos NPOP-1																				X		
Eos NPOP-2																						
STO/POP-1								X				X				X						
STO/POP-2																						

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SCHEDULE FOR OSSA CANDIDATE PAYLOADS
LENDAR YEAR QUARTER

	99		2000				2001				2002				2003				2004				2005			
	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
					X						X						X						X			
										X																
CING REQUIRED																										
CING REQUIRED																										
G SCHEDULE TBD																										
3 SCHEDULE TBD																										
CING REQUIRED																										
							X																			
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CING REQUIRED																										
		X																				X				
		X		X		X		X		X		X		X		X		X		X		X		X		X
G REQUIREMENTS TBD																										
							X													X						
CING REQUIRED																										

										X												X				
				X							X															
						X		X								X								X		
					X									X									X			
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
										X												X				

										X												X				
				X												X										
					X				X				X													

CHAPTER III

TOP LEVEL REQUIREMENTS DATABASE

A. INTRODUCTION

This chapter presents the servicing database compiled for the OSSA payloads considered in the study. Mission servicing data is contained in individual units, which are organized alphabetically by payload abbreviation. Each payload unit is paginated in the upper right hand corner with the payload abbreviation and page number. The color of the tab for each payload indicates whether it is an attached payload (yellow), a free-flyer (green), or a pressurized module (red).

A brief description of the contents of each payload unit is provided in Chapter I, Section J. A detailed definition of each of the 16 sections of a payload unit is found in Appendix B, where the Payload Information Format is explained.

As noted in Chapter I, the data presented in each payload unit has been reviewed and validated by appropriate NASA managers as of October, 1987.

ASTRO: MISSION CODE TBD

1.0 ASTRO PROGRAM AND OPERATIONS INFORMATION

1.1 Astro Point of Contact

Mr. Louis Demas
NASA/HQ
Washington, D.C. 20547
(302) 453-1690

Mr. Jack Jones
Mail Code JA-21
NASA/MSFC
Huntsville, AL 35812
(205) 544-6595

1.2 Astro Objectives

Astro collects ultraviolet (UV) imagery, spectroscopy, and polarimetry simultaneously from the same object. Astro's studies, covering the bandwidth of 450 to 3300 Angstroms, will extend UV astronomy beyond all previous efforts. Collection of data while based at the SS (rather than at the Orbiter) will allow a longer data collection period and, thus, a more-expanded observational capability.

1.3 Astro Milestone and Servicing Schedule

Launch: TBD.
First Space Station Service: Not applicable.
Servicing Interval: Not applicable.
Operational Lifetime: 1 year.

1.4 Astro Orbital Parameters

Astro is a SS attached payload. As such, it has the same orbital parameters as the Space Station.

2.0 ASTRO PHYSICAL CHARACTERISTICS

2.1 Astro Description

Three instruments comprise Astro. The Hopkins Ultraviolet Telescope (HUT) will study faint objects such as quasars, active galactic nuclei, and galaxies in the far-UV. The Ultraviolet Imaging Telescope (UIT) focuses on hot stars and galaxies in broad UV wavelengths with a wide field of view. The Wisconsin Ultraviolet Photo Polarimetry Experiment (WUPPE) examines the polarization of hot stars, galactic nuclei, and quasars. These telescopes are mounted and co-aligned on a common structure called the cruciform. This support structure attaches to the Instrument Pointing System (IPS) which maintains the pointing orientation of the instruments. To increase the stability of pointing provided by the IPS, the UIT and WUPPE each have a small secondary mirror controlled by a computer-based Image Motion Compensation System (IMCS). (Figure Astro-1 shows Astro minus the IPS.)

Two modifications will be made to convert Astro from an Orbiter experiment to a SS-attached payload. Currently, the UIT requires photographic film. When attached to the SS, the UIT will employ a CCD (charge-coupled device) to convert images to digital information for transmission to Earth. The second alteration moves Astro control from the Orbiter to the ground.

In addition to these modifications, the determination of Astro's attachment method may lead to a redesign of the PSSA (payload support strut assembly), which interfaces between Astro and the Orbiter pallet (or possibly the IPS structure). One method is to attach the double pallets (used in Orbiter transport) to the SS. No redesign of the Astro/carrier structure is required with this method. The other alternative entails the connection of either

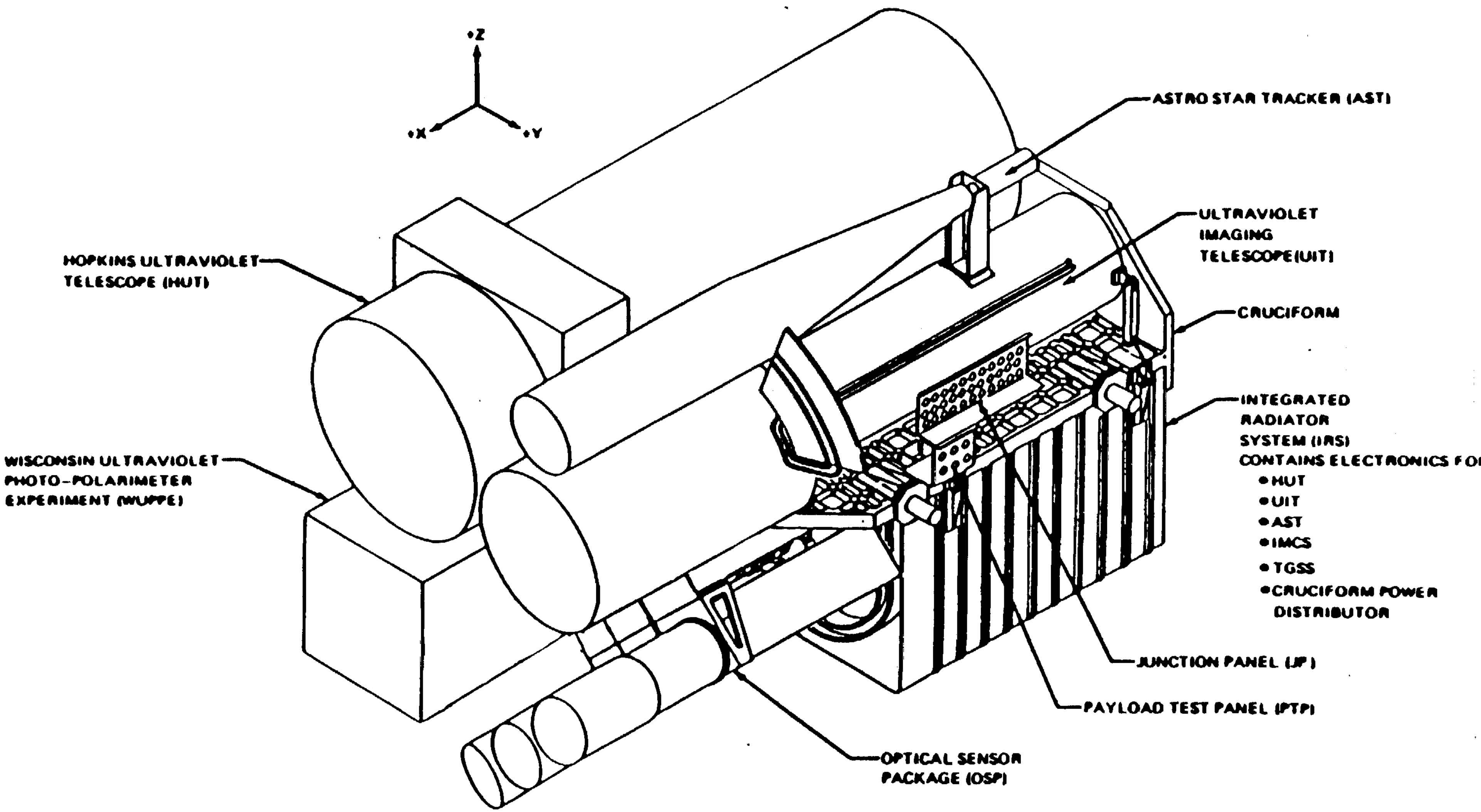

Figure Astro-1. Cruciform/Experiment Assembly

the IPS or the PSSA to the SS. In this case, either the IPS structure or the PSSA must be redesigned because the removal of the PSSA at this time from the pallets is more complicated than is desirable. Figure Astro-2 shows the present PSSA/double pallet design.

The Instrument Pointing System (IPS) and the Image Motion Compensation System (IMCS) maintain Astro's arc-second pointing accuracy requirement. While attachment of Astro near the SS center of gravity is not required, this location would minimize pointing disturbances.

Astro is capable of operating for periods of time much longer than one year. However, due to the magnitude of the analysis-demanding data which can be collected during one year of operation, Astro will return to Earth after this operation period in order to provide opportunity for other SS-attached payloads.

2.2 Astro Physical Characteristics

a. Assume that the double-pallet is used for Orbiter transport only. Assume that the IPS connects directly to the SS.
   - Mass: 4500 kg
   - Stowed Dimensions: 7.2m long x 4.0^m high x 3.2^m wide
   - Envelope: 92^ m^3
   - Deployed Dimensions: 5.8^m long x 7.5^m high x 3.2^m wide
   - Envelope: 140^m^3

b. Assume that the double-pallet attaches to the SS.
   - Mass: 5700 kg
   - Stowed Dimensions: 7.2m long x 4.2^m high x 4.8m wide.
   - Envelope: 150^m^3
   - Deployed Dimensions: 7.2^m long x 7.7^m high x 4.8m wide
   - Envelope: 270^m^3

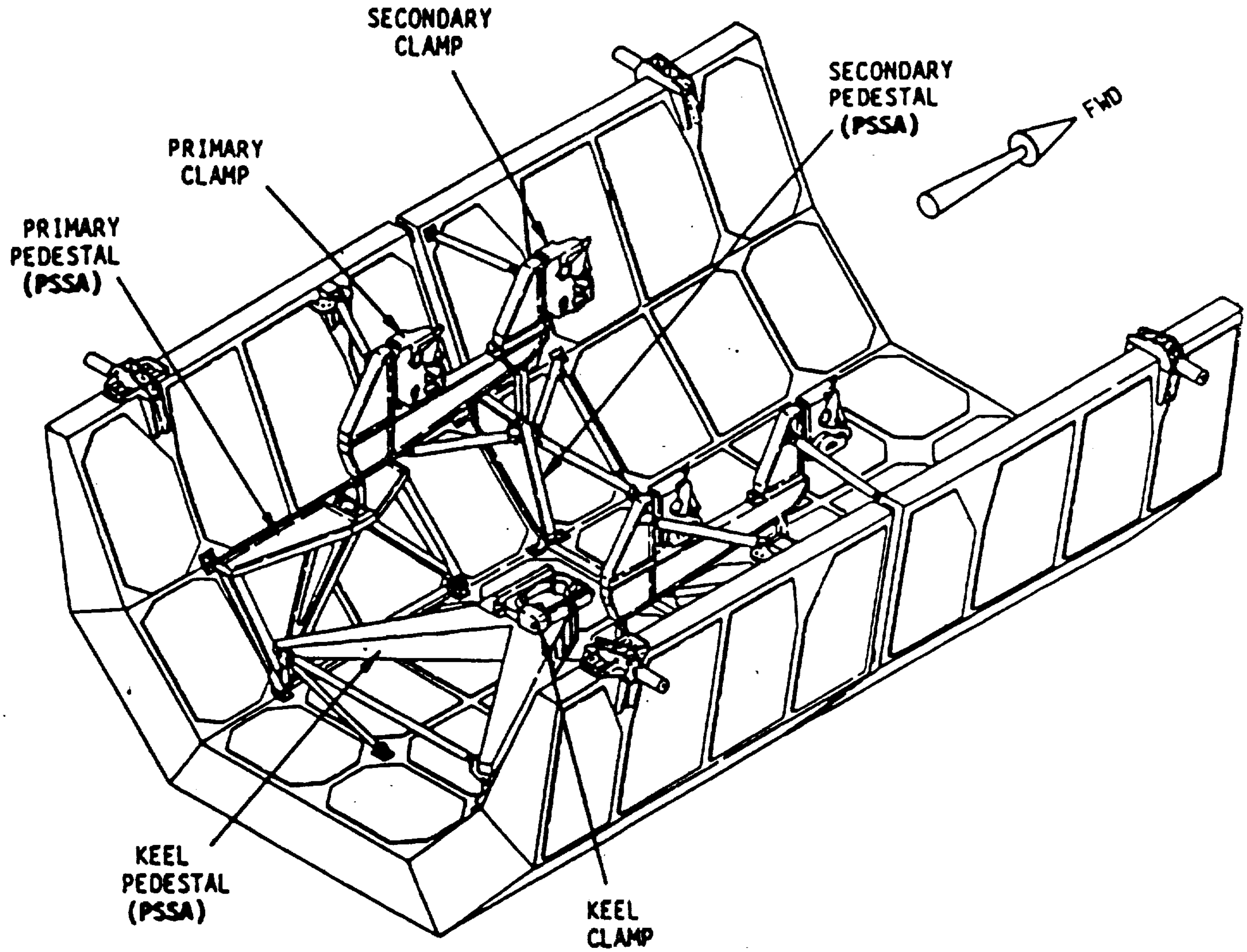

Figure Astro-2. Astro STS Carrier

2.3 Astro Moving Parts and Special Features

The IPS (instrument pointing system) points the telescopes (as a group) and maintains their orientation. The image motion compensation system (IMCS) enhances the stability of the telescope orientation by controlling small secondary mirrors in two of the telescopes.

2.4 Astro Consumables and Limited-Life Parts

None required.

3.0 ASTRO SERVICING INFORMATION

3.1 General Description of Astro Servicing

Astro has no plans for SS servicing. Contingency servicing, however, is always a possibility. The initial SS installation and final SS detachment are considered operational activities and, therefore, are not compiled in this databook as servicing activities.

3.2 Astro Background

Astro will be a proven, scientifically-established experiment by the time that it is installed at the Space Station. Instrument prototypes have been tested and flown on sounding rockets. Astro will also have been flown on the Orbiter in 1989.

3.3 Primary Role of Space Station in Servicing Astro

Not applicable.

3.4 Primary Space Station Facilities Required for Servicing Astro

Not applicable.

3.5 Space Station Personnel Required for Servicing Astro

Not applicable.

3.6 Servicing Precautions for Astro

The co-alignment of the three telescopes on the cruciform is a precision alignment. Astro transport should not induce any forces great enough to misalign this equipment. Should contingency servicing be necessary, equipment covers should be utilized to protect the three telescopes from contamination damage (see Section 6.0).

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of Astro

Not applicable.

4.0 ASTRO SERVICING SAFETY CONSIDERATIONS

4.1 Astro Hazardous Systems

Astro equipment presents no significant danger to SS personnel.

4.2 Astro Servicing Safety Precautions

Astro equipment presents no significant danger to SS personnel.

5.0 ASTRO SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 Astro Crew Convenience Features

If Astro is attached to the SS via the double pallet used to transport Astro in the Orbiter, then footholds on these pallets will aid personnel in attaching/detaching Astro. If Astro is not attached to the SS via the pallets, then the redesign of Astro's support structure will offer whatever convenience features are included in the redesign. The convenience features in this case are TBD.

5.2 Astro Mechanical Interfaces

Astro will attach to the SS either via the double pallet used in Orbiter transport or via the IPS or PSSA support structures. In either case, the mechanical fasteners are TBD.

5.3 Astro Umbilical Interfaces

a. Power

Astro requires, on average, 5000 watts (estimate based on Astro-1 operation within the Orbiter) of 28 volts power during operation and TBD watts during installation/detachment. This electrical power operates the IPS, the IMCS, the telescopes, the thermal control system, and the data/command interfaces to the SS.

b. Data

The Astro operational data rate is estimated to be 4 Mbps. Operational command rates are TBD. The interfaces are TBD.

c. Fluid

Astro requires access to fluid loop coolant to maintain coldplate temperatures between TBD ^{o}C and TBD ^{o}C (see Section 5.5).

5.4 Astro RF Communication Interface

Astro will utilize the SS communications and data handling systems.

5.5 Astro Thermal Interface

Operational thermal control will require connection to the SS coolant fluid loop. Details regarding this fluid loop interface are TBD.

6.0 ASTRO SERVICING ENVIRONMENT

6.1 Astro Pointing/Orientation Constraints

Constraints during contingency servicing activities are TBD.

6.2 Astro Contamination Concerns

Two contaminants are of concern during Astro operations or contingency servicing. Water vapor accumulation destroys the UV sensitivity of the HUT spectrograph. This potential concern is thought to be more of a ground-based problem than orbital since the spectrograph resides deep within Astro and is exposed to the

environment only through very small slits in a tightly controlled container. All of Astro's UV-detecting surfaces can also be seriously damaged by any hydrocarbon-based contaminant. SS contamination of Astro is an area that will be studied in more detail in the future.

6.3 Astro Radiation Concerns

Radiation damage is not presently identified as a major concern for Astro operations or contingency servicing. It will, however, be studied in detail in the future.

7.0 ASTRO SERVICING ACCOMMODATIONS

7.1 Astro Equipment Access

Repair or replacement of Astro components is not part of Astro's potential contingency servicing activities. Electrical subsystems could, with minor redesign, be made to be accessible for on-orbit contingency servicing. The electronics assembly is not presently designed for on-orbit access.

7.2 Astro Modularity

With minor redesign, electrical subsystems could be changed to be both modular and accessible - and thus easily replaceable during contingency servicing. At this time, however, Astro has no designated ORUs.

7.3 Astro Automated Servicing

Automated servicing is not feasible.

7.4 Astro Servicing in the Space Station Pressurized Modules

None required.

8.0 ASTRO SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Ref.Section
ORUs (including SIs)	No	No	9.0
Flight Support Equipment	No	No	10.0
Other Equipment	No	No	10.0
Servicing Equipment			
Carrier(s)	No	No	12.0
Servicing Consumables			
Propellant(s)	No	No	11.0
container(s)	No	No	11.0
Cryogen(s)	No	No	11.0
container(s)	No	No	11.0
Liquids(s)	No	No	11.0
container(s)	No	No	11.0
Gas(es)	No	No	11.0
container(s)	No	No	11.0
Other(s)	No	No	11.0
container(s)	No	No	11.0
Servicing Consumables			
Carrier(s)	No	No	12.0

9.0 ASTRO ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of Astro ORUs

No Astro components require planned servicing. Therefore, Astro has no ORUs. With minor redesign, Astro's electrical subsystems could be converted to ORU-status. As these subsystems are thought to be reliable during one year of operation, the redesigned ORUs would most likely be replaced only on a contingency basis.

9.2 Astro ORU Physical Characteristics

Not applicable.

9.3 Astro ORU Storage Requirements

Not applicable.

9.4 Other Environmental Requirements for Astro ORUs

Not applicable.

10.0 ASTRO FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 Astro Flight Support Equipment (FSE)

Astro demands no SS servicing support and, therefore, requires no servicing-associated FSE.

10.2 Astro FSE Physical Characteristics

Not applicable.

10.3 Astro FSE Storage Requirements

Not applicable.

10.4 Astro Miscellaneous Servicing Equipment

None required.

11.0 ASTRO SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

None required.

11.2 Physical Characteristics

Not applicable.

11.3 Storage Requirements

Not applicable.

12.0 CARRIERS FOR ASTRO SERVICING MATERIALS

12.1 Description of Carriers

As Astro requires no servicing, no carrier is required to transport servicing materials. A description, however, of the Astro facility carrier follows: The Astro Orbiter carrier consists of two standard STS pallets joined by the payload support strut assembly (PSSA). The Astro cruciform structure has 5 trunnions, each of which clamp to the PSSA (see Figure 2). The mass of the double pallet is 2840 kg and the volume is approximately 130 cubic meters.

12.2 STS and SS Carrier Interfaces

No carrier is planned for servicing materials since servicing is not planned for Astro. The Astro facility carrier, consisting of two standard STS pallets, interfaces with the STS via standard pallet trunnions.

12.3 Servicing Materials/Carrier Interfaces

Not applicable.

13.0 ASTRO ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

Not applicable (since this document does not address contingency servicing as per the ground rules stated in Chapter 1).

13.2 Preparatory Servicing Time Estimates

Not applicable.

13.3 Principal Servicing Time Estimates

Not applicable.

13.4 Close-Out Servicing Time Estimates

Not applicable.

14.0 ASTRO STRAWMAN SERVICING SCENARIO

14.1 Astro Strawman Servicing Mission

All SS-based activities required by Astro are considered to be operational. Therefore, no servicing strawman is applicable.

14.2 Astro Description

Not applicable.

14.3 Strawman Servicing Materials

Not applicable.

14.4 Estimated Up/Down Mass on STS to Support Astro Servicing

Not applicable.

14.5 Estimated Up/Down Volume on STS to Support Astro Servicing

Not applicable.

14.6 Storage on Space Station Required to Support Astro Servicing

Not applicable.

14.7 Astro Strawman Servicing Power Estimates

Not applicable.

14.8 Astro Strawman Servicing Times

Not applicable.

14.9 OMV Flights in Support of Astro Strawman Servicing Mission

Not applicable.

15.0 OVERALL REQUIREMENTS FOR SS SERVICING OF ASTRO

15.1 Astro Milestone and Servicing Schedule (Nominal Mission Model)

Event	Location	Date
Astro Launch	KSC	TBD
Astro Termination	SS-attached	TBD

15.2 Summary of Astro Mass Considerations*

Event	Mass Up in STS	Mass Down in STS
Launch	5700 kg	0
Termination	0	5700 kg
Total	5700 kg	5700 kg
Servicing Total	0 kg	0 kg

* Assume that the double-pallet attaches to the SS. See Sections 2.1 and 2.2.

15.3 Summary of Astro Volume Considerations*

Event	STS VOLUME UP	STS Volume Down
Launch	150^m^3	0 m^3
Termination	0 m^3	150^m^3
Total	150^m^3	150^m^3
Servicing Total	0 m^3	0 m^3

*Assume that the double-pallet attaches to the SS. See Sections 2.1 and 2.2.

15.4 Summary of Astro Power Considerations

	AVG	MAX
Astro Operational Power	5000 W	TBD
Astro Servicing Power	N.A.	N.A.
Servicing Materials Storage Power	N.A.	N.A.

15.5 Summary of Astro Servicing Time Estimates

Not applicable.

15.6 Summary of OMV Flights in Support of Astro Servicing

Not applicable.

REFERENCES

1. Astro, A New Observatory for Ultraviolet Astronomy, NASA/MSFC, 22M985.

2. Astro-1 Mission Integrated Payload Requirements Document Preliminary), February, 1987, NASA/MSFC, JA-212.

3. "Space Science and Applications Notice, Astro Investigator Program", B.I. Edelson, December 20, 1985, NASA.

THE PARTICLE ASTROPHYSICS MAGNET FACILITY (ASTROMAG): MISSION CODE SAAX0021

1.0 ASTROMAG PROGRAM AND OPERATIONS INFORMATION

1.1 ASTROMAG Point of Contact

Dr. Jonathan Ormes
Project Scientist
NASA/GSFC, Code 661
Greenbelt, MD 20771
(301) 286-5705

1.2 ASTROMAG Objectives

The ASTROMAG facility will be a research tool for high-energy astrophysics on the Space Station. The primary scientific objectives of ASTROMAG will be to:

- Study the origin and evolution of matter in the Milky Way Galaxy by direct sampling of Galactic material
- Support cosmological models by searching for antimatter and dark matter candidates
- Study the origin and the acceleration of the relativistic particle plasma in the Galaxy and its effects on the dynamics and evolution of the Galaxy

1.3 ASTROMAG Milestone and Servicing Schedule

Launch Date: 1st quarter, 1996
First Space Station Service: 1st quarter, 1996
Servicing Interval: 12 to 24 months
Operational Lifetime: TBD (estimated 6 to 10 years)

1.4 ASTROMAG Orbital Parameters

ASTROMAG will be a Space Station attached payload and therefore will have no independent orbital parameters.

2.0 ASTROMAG PHYSICAL CHARACTERISTICS

2.1 ASTROMAG Description

a. Comments

ASTROMAG will be built around a superconducting magnet and charged particle track detectors, illustrated schematically in Figure ASTROMAG-1. Together, these will form a facility in which the charge-to-mass ratio of subatomic particles can be measured. The primary components of the ASTROMAG facility will be the core magnet, the liquid helium dewar, and the particle tracking detectors (see Figure ASTROMAG-2). ASTROMAG will also incorporate its own command, control, and data handling electronics. ASTROMAG will be capable of being reconfigured and augmented over time to support a wide range of studies.

b. Superconducting Magnet

The baseline coil configuration will be a scaled-up version of the superconducting magnet designed for the High Energy Astronomy Observatory (HEAO) program in the early 1970s. The magnetic core and the first two facility experiments will be transported as separate items and assembled on-orbit. The ASTROMAG dewar, housed in a vacuum shell to permit ground testing, will contain superfluid helium at approximately 2 degrees K (see Figure ASTROMAG-3).

The magnet itself will be composed of two coils of multi-filimentary niobium-titanium in a conducting matrix, with the coils arranged such that the vector sum of their individual dipole moments is zero (see Figure ASTROMAG-4). This results in a design that will produce no significant torques on the Space Station and also will cause the ASTROMAG far-field to drop off to Earth magnitude in a reasonable distance (about 20 meters). The coils will be

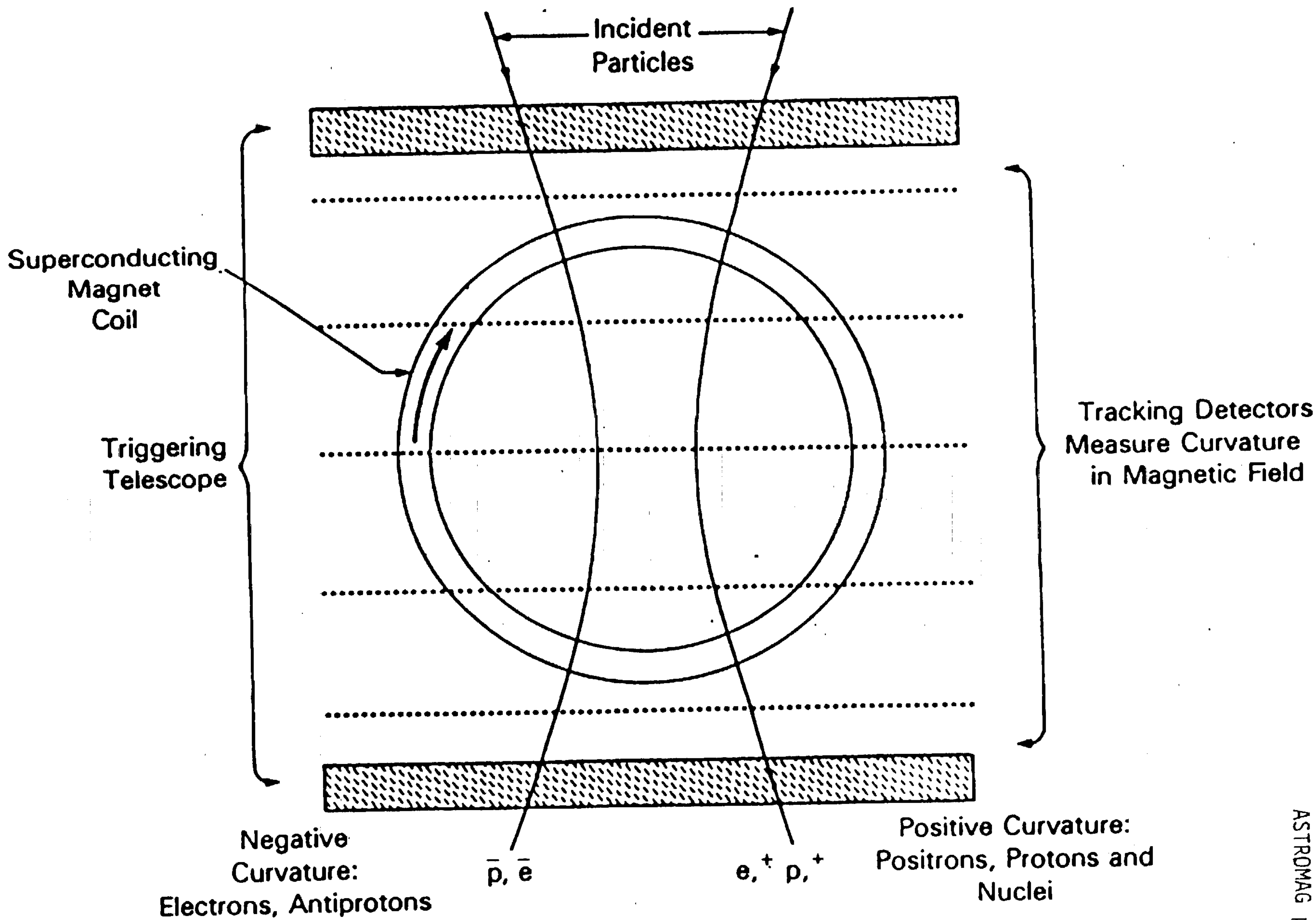

Figure ASTROMAG-1. Science Objective

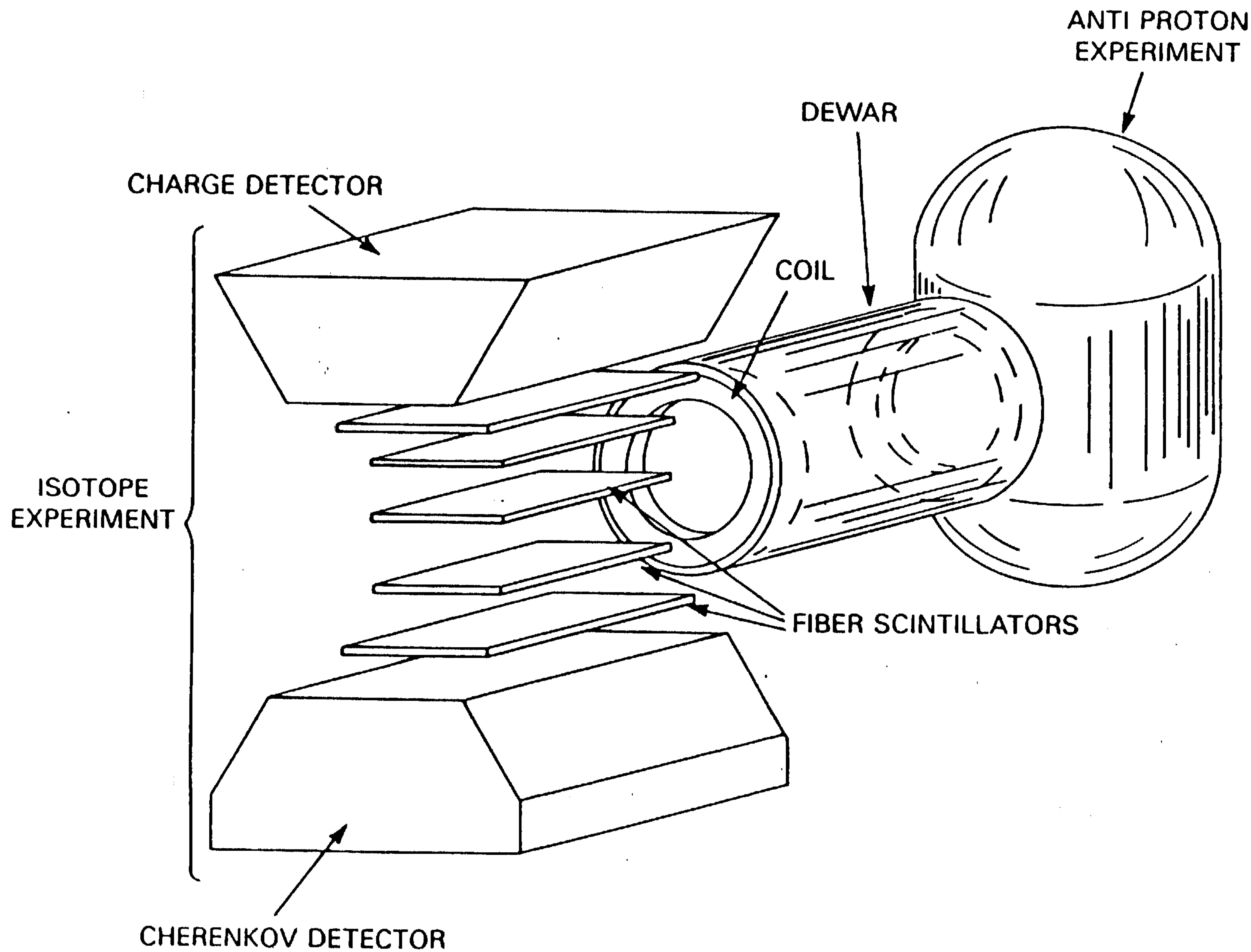

Figure ASTROMAG-2. Facility Physical Configuration

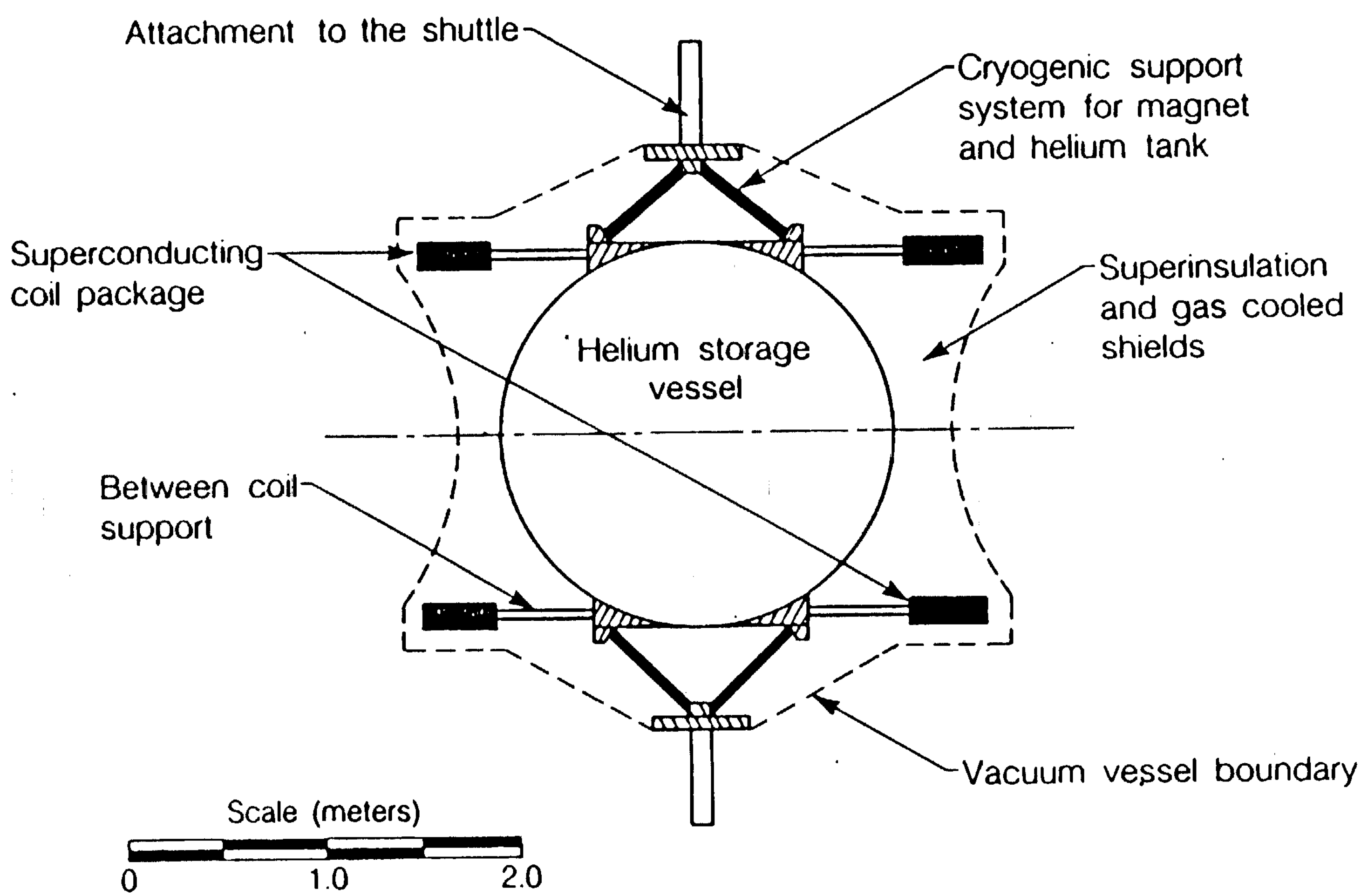

Figure ASTROMAG-3. Cryogen Dewar Configuration

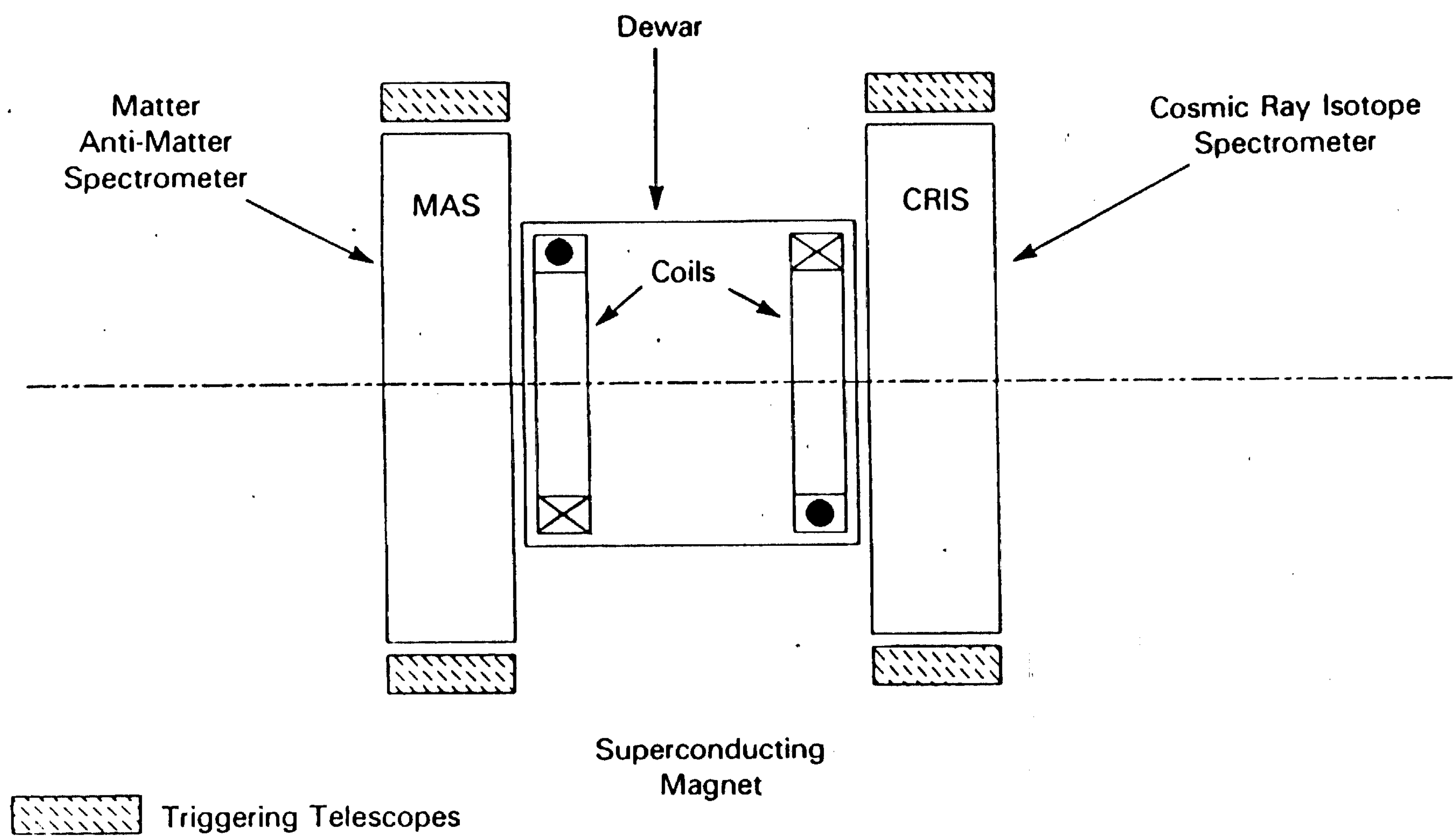

Figure ASTROMAG-4. Logical Schematic of Science Instruments

charged to their operational current using an external power source and then electrically isolated; the current and field will then persist without additional power input. The charging process will require the use of retractable electrical leads or a magnetic flux pump.

c. Science Instruments

The two candidate instruments currently under study for the ASTROMAG facility are the Matter-Antimatter Spectrometer (MAS) and the Cosmic Ray Isotope Spectrometer (CRIS). MAS will use scintillation counters, transition radiation detectors, and an electron shower counter to examine protons, antiprotons, electrons, positrons, and other low-charge particles. CRIS will employ Cherenkov counters to measure the charge and velocity of incident heavy particles (atomic number 6-28) at energies of 2 to 6 GeV/amu.

d. Support Electronics and On-Board Data System

The ASTROMAG on-board data system will pre-process experimental data and limit the bit rate required for downlink. The data system will also provide a uniform interface between each of the experiments and the Space Station for transferring of commands and of housekeeping and experimental data. It will allow either the Space Station crew or the ASTROMAG ground control center to charge/discharge the magnet coils, align and calibrate trajectory detectors, and receive status data on the magnets, dewar, and facility support subsystems. Essential features of the data system will be a standardized experiment interface and adaptable processing capabilities which will allow for instrument replacement and upgrade over the life of the facility.

2.2 ASTROMAG Physical Characteristics

a. Mass

	kg
- Superfluid Liquid Helium:	600
- Matter-Antimatter Spectrometer (MAS):	1,500
- Cosmic Ray Isotope Spectrometer (CRIS):	1,500
- Core Facility (Magnets, Dewar, Support Electronics):	1,400
- ASTROMAG Facility Total (wet):	5,000

b. Dimensions

Dimensions	Length (m)	Diameter (m)
- MAS:	1.5	3-4
- CRIS:	1.5	3-4
- Core Facility:	2	4
- Facility Total:	5	4.5

c. Envelope

- ASTROMAG Facility Total: 80 m^3

2.3 ASTROMAG Moving Parts and Special Features

No moving parts and special features are specified. ASTROMAG will be placed on a fixed mount and has no antennas, booms, or other appendages.

2.4 ASTROMAG Consumables

- 300 kg/yr superfluid helium for cooling, although ASTROMAG will be sized for a 24 to 30 month supply (i.e., 600 to 750 kg)
- Potential exists for replacement of rare-gas mixtures used in detectors. Requirements for this are TBD; solutions are to use modular gas bottles, recharge existing gas bottles, or use sealed instruments and replace them entirely.

3.0 ASTROMAG SERVICING INFORMATION

3.1 General Description of ASTROMAG Servicing

a. Assembly/Installation

ASTROMAG may utilize the Space Station capability for on-orbit assembly of the core facility with the initial experiments prior to (or during) installation on the Space Station. Connections must then be made to the SS power, data, and thermal control subsystems. Prior to commencing actual operations, ASTROMAG will undergo functional tests, and the spectrometers (MAS and CRIS) will be aligned with the magnets off, under ground control. Charging or discharging the coils will require 6 to 12 hours. The facility will then be ready to begin science operations which will be performed under ground control.

b. ASTROMAG Standard Servicing Activities

- All servicing operations for ASTROMAG will normally be performed at its attached location on the Space Station. The primary servicing activity will be the replenishment of cryogen at 12 to 24 month intervals. The magnet coils will be charged and discharged by an automated system monitored from the ground and by an SS crew member. Cryogen will be transferred via an umbilical from a storage container to the ASTROMAG dewar.
- ASTROMAG may be reconfigured with new experiments every 12 to 24 months. This will involve IVA monitoring support of robotics to remove and replace one (perhaps both) of the facility instruments.
- At intervals of TBD months (perhaps 4 to 5 times a year), the coils could be discharged in order to accommodate servicing of nearby payloads. This activity will be performed at irregular intervals when

other SS or payload EVA activity in the vicinity of ASTROMAG requires deactivation of the magnets. During this period, the ASTROMAG spectrometers could be calibrated and aligned.

- In the event of damage or malfunction or to upgrade ASTROMAG capabilities, contingency replacement of ASTROMAG facility support electronics modules will be required. It is also possible that support electronics could be tested and repaired on-orbit if adequate SS internal work station facilities are available.

3.2 ASTROMAG Background

a. Comments

Much of the technology necessary for ASTROMAG exists and is in use today. Space-borne superconducting magnets were first used in the HEAO program in the early 1970s and continue to be used in balloon-borne instruments today. The essential technology required for the planned instruments is also currently operational in high-altitude balloon experiments. For both the core magnet subsystem and the ASTROMAG experiments, there exist numerous options for development to the facility-level envisioned for Space Station flight.

b. Magnets and Dewar

The superconducting magnets and the superfluid helium dewar necessary to maintain the coils in the superconducting state follow closely from technology developed for the HEAO, IRAS, COBE, and SPACELAB II programs. The ASTROMAG magnets and dewar will be considerably larger than those developed for these prior programs and will require additional development; however, the technology is well understood, and no significant problems are expected.

Detailed studies are planned to allow the evaluation of trade-offs to optimize system size, weight, cryogen requirement, magnetic field, charge/discharge techniques, safety considerations, and modularity/accessibility to enhance assembly, integration and test, and serviceability. There are also at least two additional coil configurations (offering greater magnetic field strength at the expense of more complex design requirements) that will be evaluated.

c. <u>Trajectory Detectors</u>

The ASTROMAG science instruments, derived from current balloon-borne experiments, will be larger and will have greater sensitivity than existing particle detectors. The heart of each ASTROMAG spectrometer (MAS and CRIS) will be a position-sensing detector capable of precise particle trajectory measurements. The development effort necessary for the position sensors will be more difficult than that associated with the magnet/dewar subsystem. Various inherent systemic errors (including optimization of electronics for triggering and readout, effective calibration techniques, suppression/rejection of spurious events, and thermal stability of the detectors) are areas which will require investigation and development. ASTROMAG detectors must be increased in size (area) by a factor of 4 or 5 compared to current flight models to improve the "ridigity resolution" (i.e., Z/A precision); this will present a unique set of challenges to instrument developers. However, the expected payoff of this enhanced detector sizing combined with ~300 times greater observing time afforded by spaceflight is a two to five-fold increase in position resolution which will permit much better particle trajectory determination and more effective analysis and interpretation of event data. The basic technology necessary has already been demonstrated in a laboratory environment; transition to flight status is expected to be challenging but is entirely feasible.

3.3 Primary Role of Space Station in Servicing ASTROMAG

- Support planned facility servicing. This will involve initial assembly on-orbit, replenishing cryogen, changing out science instruments, and replacing failed or obsolete support electronics modules.
- Provide a fixed, stabilized mount that allows anti-Earth viewing for a wide field of view instrument and supplies necessary interfaces for data, power, and thermal control.

3.4 Primary Space Station Facilities Required for Servicing ASTROMAG

- Short-term external storage for cryogen, science instruments, and replacement ORUs
- Voice/video/data links to allow ground personnel to monitor and support servicing activities
- Possible use of the Mobile Remote Manipulator System (MRMS) to transport ORUs, tools, and personnel
- Possible use of an internal work area where ASTROMAG support electronics modules could be tested, reconfigured, or repaired. This activity would occur on a contingency basis only; the actual requirement for this type of support is TBD.

3.5 Space Station Personnel Required for Servicing ASTROMAG

IVA support to robotics will be required to charge and discharge the magnet, changeout science instruments, replace subsystem electronics modules, and replenish cryogens; ASTROMAG ground personnel would monitor and assist via voice, data, and CCTV.

3.6 Servicing Precautions for ASTROMAG

It is assumed that the magnet must be discharged prior to any servicing activity of ASTROMAG itself or other payloads in close proximity to ASTROMAG. ("Close" is TBD but will probably be defined to mean within 3 meters of the surface of ASTROMAG.) The cryogen replenishment tanker (CRTR) will require a shroud or sunshade to prevent direct exposure to solar flux during replenishment operations.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of ASTROMAG

ASTROMAG will be an SS attached payload and will have no remote elements requiring the use of the OMV.

4.0 ASTROMAG SERVICING SAFETY CONSIDERATIONS

4.1 ASTROMAG Hazardous Systems

The most critical hazards on ASTROMAG will be potential electrical shock and explosion of the cryogen dewar or detector gas storage bottles. There will also be hazards due to the effects of the facility's magnetic field if the coils are operating. These hazards will be eliminated as described below.

a. Shock

Electric counters will be designed with all high-voltage points insulated or otherwise protected to prevent accidental contact. In addition, it must be ensured that the magnetic circuit is always closed. This will be done by using appropriate design and fabrication techniques. The magnet coils will be designed to absorb all heat from a quench without warming above 70 degrees Kelvin (so as to avoid burning out the coils). The design will be verified by ground tests prior to launch.

b. Cryogen Dewar Integrity

When fully charged, the magnet will contain 8 to 12 MJ of energy. Since the development of a heat leak to the dewar is particularly dangerous, the magnet will be designed to isolate the energy deposited by a quench of the coils and prevent its being dumped into the liquid helium. The dewar will be designed with multiple vent paths and blow-out disks and will be tested to NASA's pressure vessel standards. The safe operation of the dewar and coils will be verified by ground test and operation prior to launch.

c. Detector Gas Storage Bottles

Detector gas storage bottles will be designed and tested to NASA's pressure vessel standards.

d. Magnetic Field

There will be three hazards from ASTROMAG'S magnetic field. First, it could cause mechanical devices (such as relays and solenoids) to malfunction; second, it could attract ferrous objects; and third, it could perturb the functioning of the EMU life support systems of nearby EVA crew members. The field strengths capable of affecting valves, relays, etc. will be confined to the immediate vicinity of the magnet and will not affect other nearby Space Station experiments or crew activities. It is assumed that the magnet will be discharged for servicing or other crew EVA activities in the immediate vicinity of ASTROMAG. ASTROMAG itself must be designed to intercept objects that are attracted to the magnets before they accelerate to speeds great enough to be destructive. This will be done either by the external surface of the ASTROMAG itself or by a specially designed shield placed around the facility.

e. Other Considerations

There will also be safety issues associated with cryogen replenishment. NASA is committed to develop this capability, and cryogen transfer demonstrations are already planned for the STS. Cryogen replenishment techniques are expected to be well-established before ASTROMAG becomes operational; exact procedures for ASTROMAG are TBD. The magnet coils will be charged and discharged automatically but will be monitored by the Space Station crew. The software and hardware associated with this operation will be designed to prevent overcharging the magnet, charging at too high a rate, or other unplanned actions which might create a hazardous situation.

4.2 ASTROMAG Servicing Safety Precautions

The magnets will be discharged prior to ASTROMAG servicing or EVA in proximity to the ASTROMAG facility. TBD procedures will be implemented to ensure crew safety during cryogen replenishment and science instrument changeouts.

5.0 ASTROMAG SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 ASTROMAG Crew Convenience Features

No crew convenience features are specified at this time, but handholds and tether rings are possible. Since ASTROMAG is intended to be assembled and serviced on-orbit, care will be taken to develop a space-serviceable design.

5.2 ASTROMAG Mechanical Interfaces

No mechanical interfaces are specified at this time. ASTROMAG will interface directly to sill and keel trunnions in the STS payload bay; ideally, these would also be used to attach ASTROMAG to the Space Station as well. Payload Interface Adapters (PIAs) and Station Interface Adapters (SIAs) are also possible mechanical interfaces between ASTROMAG and the Space Station.

5.3 ASTROMAG Umbilical Interfaces

a. Power

- 28 VDC (unregulated) during operations and servicing
- 500 watts during servicing or storage to operate heaters and monitor critical subsystems (i.e., cryogen dewar and associated equipment)
- 2,000 watts during operation
- 5 kW hours expended over 6 to 12 hours required to charge superconducting magnets; once the coils are charged, no additional power will be required for their operation

b. Data

- TBD command and data uplink and downlink rates during servicing
- 1 kbps command uplink (intermittant) during operations
- 500 kbps science data downlink (continuous) during operations
- TBD MByte data storage requirement (data storage will be required if continuous downlink is not available during experiment operation)

c. Fluid

ASTROMAG will use TBD interface for cryogen replenishment every 12 to 24 months.

5.4 ASTROMAG RF Communication Interface

ASTROMAG will provide data to the Space Station Information System (SSIS) for downlink, so no RF communication interface will be required.

5.5 ASTROMAG Thermal Interface

- Servicing or storage temperature range will be 0 to +30 degrees C; temperatures will be maintained in this range using on-board heaters and thermostats. Status of the thermal control system (i.e., active or inactive) during ASTROMAG servicing or storage is TBD.

- ASTROMAG will require use of the Space Station active thermal control system during operations; actual interface requirements (i.e., cold plates or direct connection to fluid loops) are TBD.
- ASTROMAG mean operating temperature will be +20 degrees C; allowable operating, servicing, and storage temperature range will be 0 to +30 degrees C.
- Spectrometer (i.e., MAS and CRIS) operating temperature is critical and must be maintained within +/- 2 degrees C. (It is the <u>stability</u> of the temperature within +/- 2 degrees C which is critical to accurate operation of the spectrometers; the actual target operating temperature could be set within the broad envelope of 0 to 30 degrees C as long as it is stably maintained.)

6.0 ASTROMAG SERVICING ENVIRONMENT

6.1 ASTROMAG Pointing/Orientation Constraints

ASTROMAG will be situated in a fixed mount pointing in the zenith direction (+/- 10 degrees) during both servicing and operations. Its operational attitude must be known within +/- 0.01 degree for analysis of gamma-ray data and within +/- 2 degrees for particle experiments.

6.2 ASTROMAG Contamination Concerns

ASTROMAG will be a sealed system, and the instruments will not be susceptable to contamination. ASTROMAG will vent liquid helium at the rate of approximately 7 liters/day and may perhaps vent small quantities of proportional counter gas.

6.3 ASTROMAG Radiation Concerns

ASTROMAG will not be sensitive to EMI radiation, except for requiring shielding from RF fast signals.

7.0 ASTROMAG SERVICING ACCOMMODATIONS

7.1 ASTROMAG Equipment Access

Provisions for equipment access will generally be good for all serviceable subsystems. ASTROMAG will be designed for on-orbit assembly and maintenance, and all warm instruments, electronics, and support systems will be designed for possible EVA access.

7.2 ASTROMAG Modularity

ASTROMAG science instruments (SIs) will be self-contained with standardized connectors and latches on the core facility. ASTROMAG subsystems (i.e., control electronics and data system) will be entirely modular. ASTROMAG will use standard "egg crate" Support Electronics Modules (SEMs) (about 1/3 x 1/3 x 1/2 meter) which will in turn house small Support Electronics Components (SECs) which plug into the modules. The modules will be capable of on-orbit changeout, allowing relatively simple, rapid repair or reconfiguration.

7.3 ASTROMAG Automated Servicing

Automated servicing has not yet been considered in depth. All-robotic cryogen replenishment is entirely possible if the necessary data and fluid connector interface for the umbilical can be developed. The overall modular design standard, coupled with standardization upon only a few ASTROMAG module sizes, should also make the facility a good candidate for all-robotic servicing. The sheer size of the two ASTROMAG science instruments (each perhaps 1,500 kilograms, 1.5 meters long by 4 meters in diameter) may require a combined approach of using both EVA and the MRMS to handle, store, or replace them. The smaller data system SEMs, however, are ideal candidates for all-robotic changeout.

7.4 ASTROMAG Servicing in the Space Station Pressurized Modules

SS-internal servicing is a low-probability activity for ASTROMAG. While it is possible that a malfunctioning electronics module could be repaired (given adequate on-orbit repair facilities), it is more likely that a faulty module will be replaced with spares sent from the ground.

8.0 ASTROMAG SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS-Provided	Comments	Ref. Section
ORUs (including SIs)	Yes	No	CRIS,MAS,SEM	9.0
Flight Support Equipment	Yes	No		10.0
Other Equipment	No	No		10.0
Servicing Equipment Carrier(s)*	Yes	No		12.0
Servicing Consumables				
Propellant(s)	No	No	(Attached payload)	11.0
container(s)	No	No		11.0
Cryogen(s)	Yes	Yes	Liquid helium	11.0
container(s)	Yes	Yes	Superfluid helium tanker	11.0
Liquids(s)	No	No		11.0
container(s)	No	No		11.0
Gas(es)	Yes	No	Rare gases for SI detectors	11.0
container(s)	Yes	No		11.0
Other(s)	No	No		11.0
container(s)	No	No		11.0
Servicing Consumables Carrier(s)*	Yes	No	Rare gases for SI detectors	12.0
	Yes	Yes	Liquid helium cryogen	12.0

*Carriers for servicing materials will typically be used during transportation in the STS Orbiter and/or during storage on the SS. A single carrier may be used.

9.0 ASTROMAG ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of ASTROMAG ORUs

a. Primary

- Cosmic Ray Isotope Spectrometer : CRIS
- Matter-Antimatter Spectrometer : MAS
- Support Electronics Components : SEC
- Support Electronics Modules : SEM*

*each SEM is comprised of 24 SECs

b. Secondary

No secondary ORUs are currently specified. Because of the modular nature of the ASTROMAG system and the long life expected, all ASTROMAG instruments and support systems will be designed for relatively easy changeout to allow upgrade or servicing.

9.2 ASTROMAG ORU Physical Characteristics

ORU	Mass (kg)	Dimensions (m)	Volume (m^3)	No. Used
CRIS	1,500	1.5 x 4 dia.	19	1
MAS	1,500	1.5 x 4 dia.	19	1
SEM	80	0.3 x 0.3 x 0.6	0.054	4

9.3 ASTROMAG ORU Storage Requirements

ORU	Storage Temperature Range (deg. C)	Storage Power Range (watts)
CRIS	0 to +30	500 to TBD
MAS	0 to +30	500 to TBD
SEM	0 to +30	500 to TBD

9.4 Other Environmental Requirements for ASTROMAG ORUs

None specified.

10.0 ASTROMAG FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 ASTROMAG Flight Support Equipment (FSE)

FSE will consist of SS-provided transfer umbilicals and cabling for cryogen replenishment (these may be integral to the cryogen replenishment tanker). Special Test Equipment (STE) may include a command/control console for the cryogen transfer operation (if an adequate general-purpose power/signals interface is not provided by the Space Station). Mechanical interfaces (e.g., modules, latches, etc.) will probably be metric.

10.2 ASTROMAG FSE Physical Characteristics

No information available.

10.3 ASTROMAG FSE Storage Requirements

No information available.

10.4 ASTROMAG Miscellaneous Servicing Equipment

No information available.

11.0 ASTROMAG SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

- ASTROMAG will have a maximum capacity of approximately 4,500 liters (600 kg) of liquid helium to maintain the magnet coils in the superconducting state. The magnet will be launched onboard the STS in the cold state to reduce initial on-orbit cryogen demands. The cryogen replenishment interval will be 12 to 24 months. Replenishment will be accomplished by transfer from a storage container via an insulated umbilical.
- The cryogen replenishment tanker characteristics are TBD.

- The ASTROMAG particle trajectory detectors will contain rare-gas mixtures. These gases will limit detector life; however, the amount of gas required and operational lifetimes which will be obtained are TBD. If gases must be replenished before instrument changeout, modular gas bottles will probably be used.

11.2 Physical Characteristics

a. Cryogens

Element	Mass (kg)	Dimensions (m)	Volume (m^3)	No. Used
Liquid He	600	N.A.	5	N.A.

b. Others

Element	Mass (kg)	Dimensions (m)	Volume (m^3)	No. Used
Gas	50 to 100	N.A.	TBD	N.A.
Gas Bottle	150	TBD	TBD	TBD

11.3 Storage Requirements

Element	Storage Temperature Range (deg. C)	Storage Power Range (watts)
Gas Bottle	0 to +30	TBD to TBD

12.0 CARRIERS FOR ASTROMAG SERVICING MATERIALS

12.1 Description of Carriers

It is assumed that ASTROMAG will require special carriers for transport of the containers for the ORUs and servicing equipment listed in sections 9.0 and 10.0, respectively. However, details related to these carriers (e.g., mass, dimensions, volume, and storage requirements aboard the Space Station) are TBD. Such carriers will probably be unpressurized and will be provided by the ASTROMAG program.

12.2 STS and SS Carrier Interfaces

Specific arrangements for interfacing carriers for ASTROMAG ORUs and servicing equipment with the STS Orbiter and with the Space Station (e.g., whether via trunnions, RMS grapple fixtures, umbilicals, or hard mounts and whether they remain in the Orbiter payload bay or are either temporarily or permanently stored at the Space Station) are TBD.

12.3 Servicing Materials/Carrier Interfaces

Specific arrangements for how, when, and where the servicing materials are to be removed from and returned to their carriers are TBD.

13.0 ASTROMAG ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

The ASTROMAG magnet will need to be discharged prior to each servicing activity for the ASTROMAG facility and for servicing of other attached payloads in close proximity to ASTROMAG.

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (crew-hr:min)	EVA Time (crew-hr:min)	Robotics Time (hr:min)
1. Unloading Servicing Material from STS to SS	0:30^	0:30^	0:00	0:30^
2. Transport Servicing Material to ASTROMAG Attachment Point	1:30^	1:30^	0:00	1:30^

13.3 Principal Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (crew-hr:min)	EVA Time (crew-hr:min)	Robotics Time (hr:min)
1. On-orbit Assembly of ASTROMAG facility	TBD	TBD	0:00	TBD
2. Science Instrument (ORU) Changeout	TBD	TBD	0:00	TBD
3. Liquid Helium Cryogen Replenishment	TBD	TBD	0:00	TBD

13.4 Close-Out Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (crew-hr:min)	EVA Time (crew-hr:min)	Robotics Time (hr:min)
1. Transport Servicing Material from ASTROMAG Attachment Point	1:30^	1:30^	0:00	1:30^
2. Loading of Servicing Material from SS to STS	0:30^	0:30^	0:00	0:30^

14.0 ASTROMAG STRAWMAN SERVICING SCENARIOS

14.1 ASTROMAG Strawman Servicing Missions

The following two strawman servicing missions address typical, representative, planned servicing scenarios of average complexity for ASTROMAG. The Type A strawman servicing mission encompasses the tasks required to accomplish on-orbit assembly of the ASTROMAG facility. The central cryogen dewar and two science instruments (i.e., CRIS and MAS) are transported to the Space Station via a single STS flight, and assembly occurs subsequently during the same calendar year quarter. (The additional task of attaching the assembled ASTROMAG facility to the Space Station is not included in the Type A "assembly" mission.) A portion of the Type B mission entails replenishing the liquid helium cryogen onboard ASTROMAG; this activity does not include the attendant requisite on-orbit operations for unloading the filled cryogen tanker and its carrier from the STS Orbiter and subsequently reloading the emptied tanker and its carrier back aboard the Orbiter for return to Earth, as per the ground rules presented in Chapter I of this data book. Another aspect of the Type B strawman servicing mission consists of an additional principal servicing activity selected from section 13.3 of replacing one of the two science instruments onboard ASTROMAG.

Specific activities inherent in the Type B strawman servicing mission include:

- translating the superfluid helium tanker to the ASTROMAG attachment site on the Space Station
- transferring superfluid liquid helium from the tanker into the ASTROMAG onboard cryogen dewar via attached FSE umbilicals and cabling
- returning the tanker for storage at the Space Station
- unloading a replacement science instrument with its carrier from the Orbiter payload bay

- short-term storage of the SI and its carrier at the Space Station
- translating the SI and its carrier to the ASTROMAG attachment site
- changeout of the current SI with the replacement SI
- returning the replaced SI and its carrier to temporary storage at the Space Station
- reloading the replaced SI and its carrier into the Orbiter

For Types A and B servicing missions, IVA crew support is required to monitor all servicing operations; transfer ORUs, SIs, FSE, and consumables within their carriers via the Space Station MRMS; and command/control the transfer of cryogen from its storage tanker into the ASTROMAG dewar. No EVA crew support is required.

14.2 ASTROMAG Description

The strawman servicing configuration of the overall ASTROMAG facility for Types A and B missions is the same as that presented in Section 2.2 except that the mass of the superfluid liquid helium has been depleted to 185 kg.

14.3 Strawman Servicing Materials

a. ORUs

ORUs	Mass (kg)	Dimensions (m)	Volume (m^3)	Avg. Storage Power (watts)	No.Used
CRIS (Type B mission only)	1,500	1.5 x 4 dia.	19	500	1

b. FSE and Miscellaneous Equipment

FSE	Mass (kg)	Dimensions(m)	Volume (m^3)	Power (watts)	No. Used
TBD	TBD	TBD	TBD	TBD	TBD

c. Consumables and Containers

- Consumable Cryogens: 450 kg superfluid liquid helium (Type B mission)
- Cryogen Container: Liquid helium is assumed to be available from an SS-provided portable cryogen replenishment tanker
- No Consumable Propellants
- No Consumable Liquids
- No Consumable Gases
- No "Other Consumables"

d. Carriers

Although specific arrangements for ORU, FSE, and consumables carriers for ASTROMAG are currently TBD (see section 12.0), BDM has postulated the following carrier configurations:

(1) For the Type A mission and for the cryogen replenishment portion of the Type B mission, any carriers necessary for accomplishing the facility assembly and cryogen replenishment activities are assumed to be provided by the Space Station and hence are not chargeable to the ASTROMAG payload program (see ground rules listed in Chapter I of this databook).

(2) For the Type B mission, it is assumed that the ASTROMAG payload program will provide a special carrier that will contain the science instrument to be transported to the Space Station onboard the STS Orbiter to replace the existing CRIS portion of ASTROMAG. This carrier is configured such that it can also accommodate the CRIS for return transport to Earth via the Orbiter. After its delivery to orbit by the Orbiter, the replacement SI remains in its carrier during temporary storage aboard the Space Station prior to being transported via the Space Station's MRMS to the attachment site for ASTROMAG. The replacement SI is then removed from the

carrier and replaces the CRIS aboard the ASTROMAG facility. The CRIS is installed into the SI carrier which is returned to the Space Station's storage bay for temporary storage prior to being reloaded into the Orbiter payload bay for return to Earth.

14.4 Estimated Up/Down Mass on STS to Support ASTROMAG Strawman Mission Types A and B Servicing*

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	0/1,500	0/0	0/1,500
ORU(s)	0/0	0/0	0/0
Unique FSE	0/0	0/0	0/0
Misc. Equipment	0/0	0/0	0/0
Equipment Subtotal	0/1,500	0/0	0/1,500
Equipment Carrier(s)	0/855^	0/0	0/855^
Subtotal, Equipment Mass Up	0/2,355^	0/0	0/2,355^
Subtotal, Equipment Mass Down	0/2,355^	0/0	0/2,355^
Consumables			
Consumables	0/0	0/0	0/0
Consumables Containers	0/0	0/0	0/0
Consumables Containers' Carriers	0/0	0/0	0/0
Subtotal, Consumables Mass Up	0/0	0/0	0/0
Subtotal, Consumables Mass Down	0/0	0/0	0/0
Total Mass Up	0/2,355^	0/0	0/2,355^
Total Mass Down	0/2,355^	0/0	0/2,355^

* Values for Strawman Mission Types A and B are separated by slashes and are presented in the order A/B.

14.5 Estimated Up/Down Volume on STS to Support ASTROMAG Strawman Mission Types A and B Servicing*

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	0/19	0/0	0/19
ORU(s)	0/0	0/0	0/0
Unique FSE	0/0	0/0	0/0
Misc. Equipment	0/0	0/0	0/0
Equipment Subtotal	0/19	0/0	0/19
Equipment Carriers	0/41^	0/0	0/41^
Equipment and Carriers Subtotal**	0/41^	0/0	0/41^
Consumables			
Consumables in Containers	0/0	0/0	0/0
Consumables, Containers, and Carriers	0/0	0/0	0/0
Total Volume Up	0/41^	0/0	0/41^
Total Volume Down	0/41^	0/0	0/41^

14.6 Storage on Space Station Required to Support ASTROMAG Strawman Mission Types A and B Servicing*

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	0/0	0/0	0/0
Volume (m^3)	0/0	0/0	0/0
Average Power (watts)	0/0	0/0	0/0
Temperature Range (°C)	-/-	-/-	-/-
Temporary Storage			
Mass (kg)	0/2,355^	0/0	0/2,355^
Volume (m^3)**	0/41^	0/0	0/41^
Average Power (watts)	0/500	0/0	0/500
Temperature Range (°C)	-/0 to +30	-/-	-/-

* Values for Strawman Mission Types A and B are separated by slashes and are presented in the order A/B.

** The volume of the "equipment" is presumed to be totally contained within the volume of its host carrier.

14.7 ASTROMAG Strawman Mission Types A and B Servicing Power Estimates*

	Servicing Mode (watts)		Operational** Mode (watts)	
	AVG	MAX	AVG	MAX
ASTROMAG (Bus + Instruments)	500/500	TBD/TBD	2,000	TBD

* Values for Strawman Mission Types A and B are separated by slashes and are presented in the order A/B.

**Operational values shown for reference purposes.

14.8 ASTROMAG Strawman Servicing Times

a. Strawman Type A

Activity	Elapsed Time (hr:min)	IVA Time (crew-hr:min)	EVA Time (crew-hr:min)	Robotics Time (hr:min)
1. On-orbit Assembly of ASTROMAG Facility	TBD	TBD	0:00	TBD
TOTALS	TBD	TBD	0:00	TBD

b. Strawman Type B

Activity	Elapsed Time (hr:min)	IVA Time (crew-hr:min)	EVA Time (crew-hr:min)	Robotics Time (hr:min)
1. Unload Servicing Materials from STS to SS	0:30^	0:30^	0:00	0:30^
2. Transport Servicing Materials to ASTROMAG	1:30^	1:30^	0:00	1:30^
3. Changeout One SI	TBD	TBD	0:00	TBD
4. Replenish Liquid Helium Cryogen	TBD	TBD	0:00	TBD
5. Transport Servicing Materials from ASTROMAG	1:30^	1:30^	0:00	1:30^
6. Load Servicing Materials from SS to STS	0:30^	0:30^	0:00	0:30^
TOTALS	4:00^ + TBD	4:00^ + TBD	0:00	4:00^ + TBD

14.9 OMV Flights in Support of ASTROMAG Strawman Mission Types A and B Servicing Missions

None - ASTROMAG is a payload which is permanently attached to the Space Station.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF ASTROMAG

15.1 ASTROMAG Milestone and Servicing Schedule

Event	Location	Date	Comments
ASTROMAG Launch	STS-ETR	1st quarter, 1996	
1st Servicing	SS	1st quarter, 1996	Type A
2nd Servicing	SS	3rd quarter, 1997	Type B
3rd Servicing	SS	1st quarter, 1999	Type B
4th Servicing	SS	3rd quarter, 2000	Type B
5th Servicing	SS	1st quarter, 2002	Type B
6th Servicing	SS	3rd quarter, 2003	Type B
7th Servicing	SS	1st quarter, 2005	Type B
ASTROMAG Mission Termination	STS-ETR	1st quarter, 2006	

15.2 Summary of ASTROMAG Mass Considerations

a. ASTROMAG in Operational/Servicing Configurations

ASTROMAG Mass (dry):	4,400 kg
Consumables Mass:	600 kg*
ASTROMAG Mass : (total)	5,000 kg

b. ASTROMAG Servicing Mass Up and Down in STS*

Event	Quarter, CY	Mass Up (kg)	Mass Down (kg)	Quarter, CY
ASTROMAG Launch	1st, 1996	5,000	0	1st, 1996
1st Servicing	1st, 1996	0	0	2nd, 1996
2nd Servicing	3rd, 1997	2,355^	2,355^	4th, 1997
3rd Servicing	1st, 1999	2,355^	2,355^	2nd, 1999
4th Servicing	3rd, 2000	2,355^	2,355^	4th, 2000
5th Servicing	1st, 2002	2,355^	2,355^	2nd, 2002
6th Servicing	3rd, 2003	2,355^	2,355^	4th, 2003
7th Servicing	1st, 2005	2,355^	2,355^	2nd, 2005
ASTROMAG Mission Termination	1st, 2006	0	4,400**	1st, 2006
Totals		19,130^	18,530^	
Servicing Totals***		14,130^	14,130^	

* STS flights will normally occur prior to and following each ASTROMAG servicing. The table indicates "mass up" required for the servicing and "mass down" resulting from the servicing.

** Assumes onboard cryogen tank retains 0 kg of liquid helium.

*** Excludes initial ASTROMAG launch mass and mission termination flight mass. These are chargable to payload operations.

c. ASTROMAG Servicing Temporary Storage Mass on Space Station

Calendar Year	97	98	99	00	01	02	03	04	05
Storage Mass (kg)									
Unpressurized	2,355^	0	2,355^	2,355^	0	2,355^	2,355	0	2,355^
Pressurized	0	0	0	0	0	0	0	0	0
TOTAL	2,355^	0	2,355^	2,355^	0	2,355^	2,355^	0	2,355^

15.3 Summary of ASTROMAG Volume Considerations

a. ASTROMAG Volume

Operational Configuration: 80 m^3
Servicing Configuration: 80 m^3
Storage/Transportation Configuration: 80 m^3

b. ASTROMAG Servicing Volumes Up and Down in STS *

Event	Quarter, CY	Volume Up (m^3)	Volume Down (m^3)	Quarter, CY
ASTROMAG Launch	1st, 1996	80	0	1st, 1996
1st Servicing	1st, 1996	0	0	2nd, 1996
2nd Servicing	3rd, 1997	41^	41^	4th, 1997
3rd Servicing	1st, 1999	41^	41^	2nd, 1999
4th Servicing	3rd, 2000	41^	41^	4th, 2000
5th Servicing	1st, 2002	41^	41^	2nd, 2002
6th Servicing	3rd, 2003	41^	41^	4th, 2003
7th Servicing	1st, 2005	41^	41^	2nd, 2005
ASTROMAG Mission Termination	1st, 2006	0	80	1st, 2006
Totals		326^	326^	
Servicing Totals**		246^	246^	

* STS flights will normally occur prior to and following each ASTROMAG servicing. The table indicates "volume up" required for the servicing and "volume down" resulting from the servicing.

** Excludes initial payload launch volume and mission termination flight volume. These are chargable to payload operations.

c. ASTROMAG Servicing Temporary Storage Volume on Space Station

Calendar Year	97	98	99	00	01	02	03	04	05
Storage Volume (m^3)									
Unpressurized	41^	0	41^	41^	0	41^	41^	0	41^
Pressurized	0	0	0	0	0	0	0	0	0
Total	41^	0	41^	41^	0	41^	41^	0	41^

15.4 Summary of ASTROMAG Power Considerations

	AVG	MAX
Operational Power (watts)	2,000	TBD
Servicing Power (watts)	500	TBD
Storage Power, Servicing Materials (watts)	500	TBD

15.5 Summary of ASTROMAG Servicing Time Estimates

Calendar Year	96	97	98	99	00	01	02	03	04	05	Total
Elapsed Time (hr:min)	TBD	4:00^+TBD	0:00	4:00^+TBD	4:00^+TBD	0:00	4:00^+TBD	4:00^+TBD	0:00	4:00^+TBD	24:00^+TBD
IVA Time (crew-hr:min)	TBD	4:00^+TBD	0:00	4:00^+TBD	4:00^+TBD	0:00	4:00^+TBD	4:00^+TBD	0:00	4:00^+TBD	24:00^+TBD
EVA Time (crew-hr:min)	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00
Total Crew Time (crew-hr:min)	TBD	4:00^+TBD	0:00	4:00^+TBD	4:00^+TBD	0:00	4:00^+TBD	4:00^+TBD	0:00	4:00^+TBD	24:00^+TBD
Robotics Time (hr:min)	TBD	4:00^+TBD	0:00	4:00^+TBD	4:00^+TBD	0:00	4:00^+TBD	4:00^+TBD	0:00	4:00^+TBD	24:00^+TBD

15.6 Summary of OMV Flights in Support of ASTROMAG Servicing

N.A.

REFERENCES

1. OSSA Space Station Servicing Data Book, The BDM Corporation, November 6, 1985.

2. Interim Report of the Astromag Definition Team, The Particle Astrophysics Magnet Facility ASTROMAG, J. F. Ormes, M. Israel, M. Wiedenbeck, and R. Mewaldt, August 1986.

3. Operations Scenarios: ASTROMAG, AXAF, HRSO, SIRTF, HST, and GRO (Draft), The BDM Corporation, November 1986.

4. Mission Requirements Data Base (MRDB), NASA/JSC, January 17, 1987.

5. Interviews with Dr. Jonathan Ormes, ASTROMAG Project Scientist, on February 17, May 21, and October 21, 1987.

6. Interview with Dr. Steve Castles, NASA GSFC Code 713.1, on October 29, 1987.

ASTROMETRIC TELESCOPE FACILITY (ATF): MISSION CODE SAAX015

1.0 ATF PROGRAM AND OPERATIONS INFORMATION

1.1 ATF Points of Contact

Mr. Kenji Nishioka
NASA/ARC
Mail Stop 244-14
Moffet Field, California 94035
(415) 694-6540

1.2 ATF Objectives

ATF's primary objective is the search for planetary systems outside our solar system. It will accomplish this objective by precisely measuring changes in relative positions of target stars with respect to reference stars. ATF is designed to detect Neptune/Uranus class planets out to 10 parsecs. It will also be able to support many other astrophysics research activities.

1.3 ATF Milestone and Servicing Schedule

Launch: 4th quarter, 1996.

First Space Station Service: 4th quarter, 1996.

Servicing Interval: 5 years.

Operational Lifetime: 20 years.

1.4 ATF Orbital Parameters

ATF is an attached payload, therefore orbital parameters are those of the space station.

2.0 ATF PHYSICAL CHARACTERISTICS

2.1 ATF Description

The ATF facility consists of a prime focus optical telescope with a Ronchi ruling at the focus to modulate star signals, a multichannel astrometric photometer (MAP) to detect the modulated signals and associated electronics equipment. Additional electronics are in the pressurized module to supplement the Space Station standard display and control console for on-orbit operations of ATF (reference Figure ATF-1 and ATF-2).

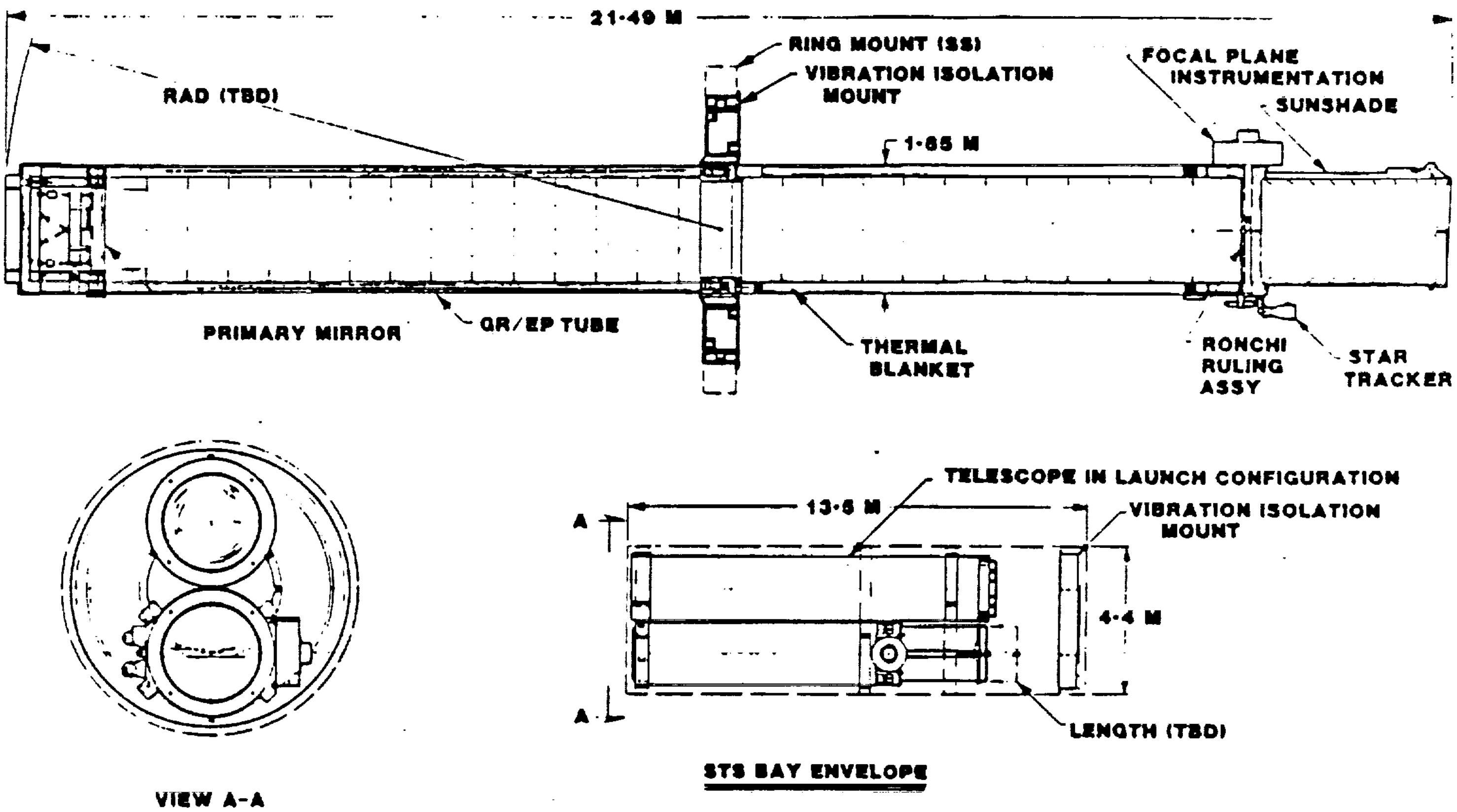

Figure ATF-1. The Astrometric Telescope Facility

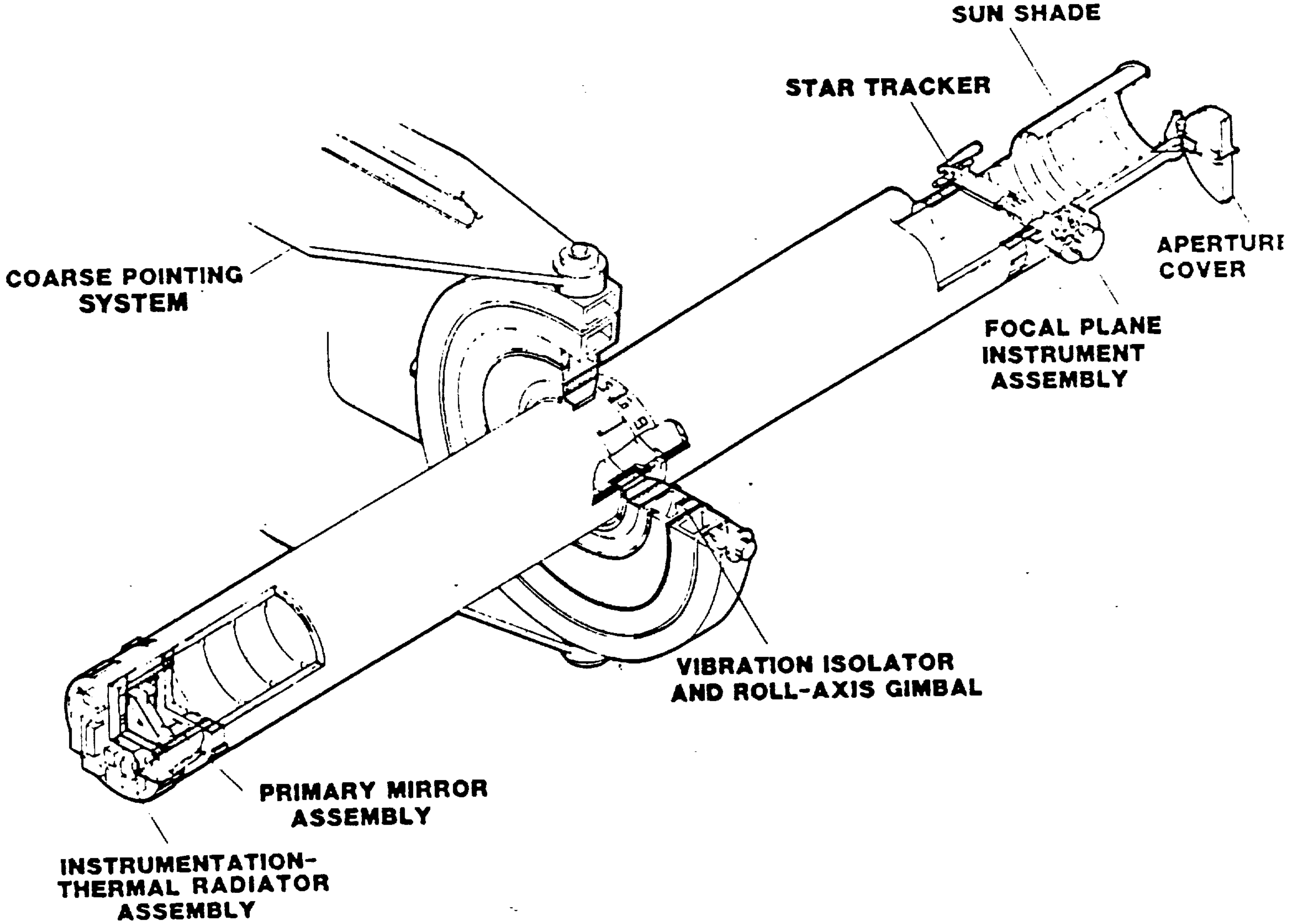

Figure ATF-2. The Mounted ATF

2.2 ATF Physical Characteristics

a. Mass

Telescope	:	5105 kg
Telescope Cradle	:	835 kg
Vibration Isolation System Cradle	:	440 kg
Electronics Support modules (for internal Station control console)	:	40 kg
Total Launch Mass	:	6420 kg

b. Dimensions

The primary mirror aperture will be approximately 1.25 meters in diameter; focal length will be on the order of 16.25 meters. The telescope is approximately 1.85 meters in diameter and 21.49 meters in length.

c. Envelope

The ATF envelope, excluding the pointing mount, is about 3 meters in diameter and 21.49 meters long (including sunshade). In its launch configuration ATF is transported in three pieces occupying an envelope measuring 4.4 meters in diameter by 13.5 meters in length for a volume of 205 m^3.

2.3 ATF Moving Parts and Special Features

There is a moving Ronchi ruling at the focal plane and the MAP uses movable pick-ups to detect individual star signals. Other moving parts are associated with the system vibration isolation assembly and the SS provided payload pointing system.

2.4 ATF Consumables

None required.

3.0 ATF SERVICING INFORMATION

3.1 General Description of ATF Servicing

ATF requires two forms of servicing, on-orbit assembly as well as ORU changeout. ATF will be transported by the orbiter in three major packages. These must then be assembled in the SS servicing bay and then attached to the payload pointing system on the upper boom. In addition, all mechanical and electronic components will be designed for repair and replacement. Crew IVA/EVA is planned for both forms of servicing. ATF plans on utilizing the Space Station Logistics Modules for transporting servicing materials to and from the Space Station.

3.2 ATF Background

No information available.

3.3 Primary Role of Space Station in Servicing ATF

As an attached payload, Space Station is the planned servicing site for the ATF. Space Station will supply the crew, equipment and resources necessary to service ATF. ATF will supply the servicing materials (eg, replacement ORUs).

3.4 Primary Space Station Facilities Required for Servicing ATF

- Mobile Servicing Center/Remote Manipulator System
- Logistics Module
- IVA Control and Display Console
- Internal Workstation (for contingency repair of ORUs)
- Servicing Bay (for on-orbit assembly)

3.5 Space Station Personnel Required for Servicing ATF

- Trained technicians on SS.
- Specialists supporting from the ground.
- EVA/IVA Crewmembers

3.6 Servicing Precautions for ATF

The Relay optics are housed in a sealed structural assembly to prevent contamination during servicing and assembly. The aperture cover, upon command, can be closed to protect the telescope optics and Ronchi ruling during maintenance operations.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of ATF

None; ATF is an attached payload.

4.0 ATF SERVICING SAFETY CONSIDERATIONS

4.1 ATF Hazardous Systems

Nominal precautions required for electrical power and magnetic fields.

4.2 ATF Servicing Safety Precautions

TBD.

5.0 ATF SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 ATF Crew Convenience Features

TBD.

5.2 ATF Mechanical Interfaces

The ATF telescope requires that the facility be able to support mechanical interfaces with the SS:

- For assembly and installation, the ATF provides the mechanical attach points on each subassembly necessary for manipulation and alignment of the pieces
- These attach points will be designed to accommodate an interface with either the Mobile Servicing Center (MSC) or astronaut EVA.
- ATF will provide SS Service Bay attach points for use during either assembly or repair
- The ATF control console will be mounted inside a manned module and will be designed for standard electronics rack mounting.

5.3 ATF Umbilical Interfaces

a. Power

Servicing power requirements are TBD. ATF interfaces to the SS power bus at its attached payload site through station supplied accommodations equipment. This power interface should be compatible with the Servicing Bay. The average optional power requirement is 1.41 kW, and the peak power is 2.53 kW during ATF slews.

b. Data

Servicing data rates are TBD. All ATF data and commands will be carried over the SS DMS Network System.

c. Fluids

TBD. (ATF may use active thermal control supplied by SS if available and convenient).

5.4 ATF RF Communication Interface

All ATF information, whether data or commands, will be carried over the SS Data Management System (DMS) Network.

5.5 ATF Thermal Interface

TBD.

6.0 ATF SERVICING ENVIRONMENT

6.1 ATF Pointing/Orientation Constraints

a. Exposure to Light

With aperture doors closed there are no orientation constraints for servicing. ATF will be under SS control during servicing and can be oriented as required to provide maximum access to ATF equipment for the EVA astronauts.

6.2 ATF Contamination Concerns

ATF is sensitive to gases or other products that could deposit or condense on the optical surfaces. To help prevent this contamination, the primary mirror is maintained above the ambient temperature. All optical elements are enclosed by an aperture door which is closed for servicing or in the event of an anomaly.

6.3 ATF Radiation Concerns

None expected.

7.0 ATF SERVICING ACCOMMODATIONS

7.1 ATF Equipment Access

Will be designed for ease of access and modular changeout.

7.2 ATF Modularity

Components that are expected to have a finite life will be designed for modular changeout.

7.3 ATF Automated Servicing

Robotics may be appropriate for module changeout.

7.4 ATF Servicing in the Space Station Pressurized Modules

Use of servicing bay would be a major advantage to provide additional protection against contamination.

8.0 ATF SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Comments	Ref. Section
ORU(s) (including SIs)	yes	no		9.0
Flight Support Equipment	yes	no		10.0
Other Equipment	yes	no		10.0
Servicing Equipment Carrier(s)	yes	yes	Logistics Modules	12.0

Servicing Consumables				
Propellant(s)	no	no		11.0
container(s)	no	no		11.0
Cryogen(s)	no	no		11.0
container(s)	no	no		11.0
Liquids(s)	no	no		11.0
container(s)	no	no		11.0
Gas(es)	no	no		11.0
container(s)	no	no		11.0
Other(s)	no	no		11.0
container(s)	no	no		11.0
Servicing Consumables Carrier(s)	no	no		12.0

9.0 ATF ORBITAL REPLACEABLE UNITS (ORUs)

a. Primary

No information available.

b. Secondary

No information available.

9.2 ATF ORU Physical Characteristics

a. Mass

- ORUs : 500 kg

This represents the mass of a number of modules which woud be required on a typical servicing mission.

b. Volume

- ORUs : 3 m^3

9.3 ATF ORU Storage Requirements

Storage Mass : 750 kg

Storage Volume : 8.0 m^3 (unpressurized storage volume)

Power Requirements : TBD

Note: The storage mass and volume for the ORUs includes the FSE equipment container that remains with the ORUs during transport and storage. See section 10.2.

9.4 Other Environmental Requirements for ATF ORUs

No information available.

10.0 ATF FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 ATF Flight Support Equipment (FSE)

The initial launch of ATF includes about 1275 kg of FSE, i.e., the telescope cradle and the vibration isolation assembly cradle. Although this equipment may be useful in supporting the on-orbit assembly of ATF, it sprimary purpose is to support the ATF and vibration isolation assembly during launch in the STS. Consequently, this equipment is not included here as FSE for servicing. However, on subsequent servicing missions, replacement ORUs will be transported in an equipment container

that provides structural support to the ORUs and provides the interface to the Stations' Unpressurized Logistics Module.

10.2 ATF FSE Physical Characteristics

- Mass : 250 kg
- Dimensions : 2m x 2m x 2m (approximately)
- Volume : 8.0 m^3

10.3 ATF FSE Storage Requirements

- Storage Mass : 250 kg
- Storage Volume : 8.0 m^3
- Temperature Range : TBD
- Storage Power : TBD

10.4 Miscellaneous Servicing Equipment

Servicing test equipment to augment the capability of the control and display panel(s) located in the pressurized modules may be required. This equipment would be transported in the Pressurized Logistics Module. Its estimated mass and volume are 100 kilograms and 0.5 m^3, respectively.

11.0 ATF SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

None required.

11.2 Physical Characteristics

Not applicable.

11.3 Storage Requirements

Not applicable.

12.0 CARRIERS FOR ATF SERVICING MATERIALS

12.1 Description of Carriers

ATF will use the Station's Logistics Modules for servicing equipment transport. The ORU container for Logistics Module Transport is treated as FSE and was described previously in sections 10.2 and 10.3.

12.2 STS and SS Carrier Interfaces

Logistics Module Interfaces to the STS and SS are a SS Program responsibility.

12.3 Servicing Materials/Carrier Interfaces

No information available.

13.0 ATF ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

No information available.

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotic Time (hr:min)
1. Unloading Servicing Material from STS to SS	0:30^	0:30^	0:00^	0:30^
2. Transport Servicing Material To ATF	1:30^	3:00^	3:00^	1:30^

13.3 Principal Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotic Time (hr:min)
1. Assembly	45:00^	45:00^	80:00^	20:00^
2. ORU Changeout	4:15^	6:30^	8:30^	2:15^

13.4 Close-out Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotic Time (hr:min)
1. Transport Servicing Material From ATF	1:30^	3:00^	3:00^	1:30^
2. Loading of servicing materials from SS to STS	0:30^	0:30^	0:00^	0:30^

14.0 ATF STRAWMAN SERVICING SCENARIO

14.1 ATF STRAWMAN SERVICING MISSION

The first servicing scenario, strawman A, is on-orbit assembly of ATF. This will occur in either the servicing bay or at its attached payload site. The second servicing scenario, strawman B, will be the replacement of mechanical and electronic component ORUs. This servicing will occur at the Space Station with material supplied by the orbiter.

14.2 ATF Description

ATF's servicing configuration is the same as its operational configuration.

14.3 Strawman Servicing Materials

a. ORUs

Type A Mission: Assembly only, no ORUs

Type B Mission: Mechanical and Electronic component ORUs (number is TBD) with at total mass and volume of 500 kg and 3.0 m^3, respectively.

b. FSE and Miscellaneous Servicing Equipment

Type A Mission: None

Type B Mission: ORU transport container with estimated mass and volume of 250 kg and 8.0 m^3, respectively. Also, servicing test equipment for use in the pressurized modules. Estimated mass and volume is 100 kg and 0.5 m^3.

c. Consumables and Containers

Type A Mission: None

Type B Mission: None

d. Carriers

Type A Mission: None

Type B Mission: None (will utilize the Space Station Logistics Modules)

14.4 Estimated Up/Down Mass on STS to Support ATF Strawman Servicing

a. Strawman Servicing Mission Type A

No servicing materials identified.

b. Strawman Servicing Mission Type B

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	0	0	0
ORU(s)	500	0	500
Unique FSE	250	0	250
Misc. Equipment	0	100	100
Equipment Subtotal	750	100	850
Equipment Carrier(s)	0	0	0
Subtotal, Equipment Mass Up	750	100	850
Subtotal, Equipment Mass Down	750	100	850
Consumables			
Consumables	0	0	0
Consumables Containers	0	0	0
Consumables Containers' Carriers	0	0	0
Subtotal, Consumables Mass Up	0	0	0
Subtotal, Consumables Mass Down	0	0	0
Total Mass Up	750	100	850
Total Mass Down	750	100	850

14.5 Estimated Up/Down Volume on STS to Support ATF Strawman Servicing

a. Strawman Servicing Mission Type A

No servicing materials identified.

b. Strawman Servicing Mission Type B

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	0	0	0
ORU(s)	3.0	0	3.0
Unique FSE	8.0	0	8.0
Misc. Equipment	0	0.5	0.5
Equipment Subtotal*	8.0*	0.5	8.5*
Equipment Carriers	0	0	0
Subtotal, Equipment Mass Up	8.0	0.5	8.5
Subtotal, Equipment Mass Down	8.0	0.5	8.5
Consumables			
Consumables	0	0	0
Consumables Containers	0	0	0
Consumables Containers Carriers	0	0	0
Subtotal, Consumables Mass Up	0	0	0
Subtotal, Consumables Mass Down	0	0	0
Total Volume Up	8.0	0.5	8.5
Total Volume Down	8.0	0.5	8.5

* The ORUs fit within the volume of the ORU container (FSE) so that their volumes are not additive for transport calculations.

14.6 Storage on Space Station Required to Support Strawman ATF Servicing

a. Strawman Servicing Mission Type A

No storage requirements identified.

b. Strawman Servicing Mission Type B

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	0	0	0
Volume (m^3)	0	0	0
Average Power (watts)	0	0	0
Temperature Range (^oC)	-	-	
Temporary Storage			
Mass (kg)	750	100	850
Volume (m^3)	8.0	0.5	8.5
Average Power (watts)	TBD	TBD	TBD
Temperature Range (^oC)	TBD	TBD	

14.7 ATF Strawman Servicing Power Estimates

	Operational Mode (Watts)		Servicing Mode (Watts)	
	AVG	MAX	AVG	MAX
ATF (Bus + Instruments)	1410	2530	TBD	TBD

14.8 ATF Strawman Servicing Times

a. Strawman A

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Assembly	45:00^	45:00^	80:00^	20:00^

b. Strawman B

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotic Time (hr:min)
1. Unloading Servicing Material from STS to SS	0:30^	0:30^	0:00^	0:30^
2. Transport Servicing Material To and From ATF	3:00^	6:00^	6:00^	3:00^
3. ORU Changeout	4:15^	6:30^	8:30^	2:15^
4. Loading of Service Material from SS to STS	0:30^	0:30^	0:00^	0:30^
Totals	8:15^	13:30^	14:30^	6:15^

14.9 OMV Flights in Support of ATF Strawmen Servicing Mission

None required.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF ATF

15.1 ATF Milestones and Servicing Schedule (Nominal Mission Model)

Event	Location	Date	Comment
Payload Launch	STS	4th quarter, 1996	
1st Servicing	SS	4th quarter, 1996	Type A
2nd Servicing	SS	4th quarter, 2001	Type B
3rd Servicing	SS	4th quarter, 2006	Type B
4th Servicing	SS	4th quarter, 2011	Type B
ATF Mission Termination		4th quarter, 2016	

15.2 Summary of ATF Mass Considerations

a. ATF in Operational/Servicing Configurations

ATF Mass (dry):	5145 kg
Consumables Mass:	0 kg
ATF Mass (total):	5145 kg

b. ATF Servicing Mass Up and Down in STS

Note: Totals are through year 2005 only.

Event	Mass Up (kg)	Mass Down (kg)
Launch	6420	
1st Servicing	0	0
2nd Servicing	850	850
Payload Mission Termination		6420
Totals	7270	7270
Servicing Totals*	850	850

* Servicing Totals do not include initial launch mass or mission termination mass, these are chargeable to operations.

c. ATF Servicing Storage Mass on Space Station

Calendar Year	96	97	98	99	00	01	02	03	04	05
Storage Mass (kg)										
Unpressurized	0	0	0	0	0	750	0	0	0	0
Pressurized	0	0	0	0	0	100	0	0	0	0
Total	0	0	0	0	0	850	0	0	0	0

15.3 Summary of ATF Volume Considerations

a. ATF Volume

Operational Configuration:	152	m^3
Servicing Configuration:	152	m^3
Storage/Transportation Configuration:	205	m^3

b. ATF Servicing Volumes Up and Down in STS

Note: Summary is through year 2005 only.

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	205	
1st Servicing	0	0
2nd Servicing	8.5	8.5
Payload Mission Termination		205
Totals	213.5	213.5
Servicing Totals*	8.5	8.5

* Servicing totals do not include initial launch mass or mission termination mass, these are chargeable to operations.

c. ATF Servicing Storage Volume on Space Station

Calendar Year	96	97	98	99	00	01	02	03	04	05
Storage Volume (m^3)										
Unpressurized	0	0	0	0	0	8.0	0	0	0	0
Pressurized	0	0	0	0	0	0.5	0	0	0	0
Total	0	0	0	0	0	8.5	0	0	0	0

15.4 Summary of ATF Power Considerations

	AVG	MAX
Operational Power (watts)	1410	2530
Servicing Power (watts)	TBD	TBD
Storage Power, Servicing Materials (watts)	TBD	N.A.

15.5 Summary of ATF Servicing Times

Calendar Year	96	97	98	99	00	01	02	03	04	05
Elapsed Time (Hrs)	45:00^	0	0	0	0	8:15^	0	0	0	0
IVA Time (Crew-Hrs)	45:00^	0	0	0	0	13:30^	0	0	0	0
EVA Time (Crew-Hrs)	80:00^	0	0	0	0	14:30^	0	0	0	0
Total Crew Time (Crew-Hrs)	125:00^	0	0	0	0	28:00^	0	0	0	0
Robotic Time (hrs)	20:00^	0	0	0	0	6:15^	0	0	0	0

Note: Servicing occurs in the 4th quarter of the years indicated.

15.6 Summary of OMV Flights in Support of ATF Servicing

None. OMV is not required.

REFERENCES

1. Interview with Ken Nishioka, ARC, July 6, 1987.

2. "Astrometric Telescope Facility: Preliminary Systems Definition Study, Volume I: Executive Summary." Ames Research Center, Moffett Field, California, 94035.

3. "Astrometric Telescope Facility: Preliminary Systems Definition Study, Volume II: Technical Description." Ames Research Center, Moffett Field, California 94035.

4. Interview with Ken Nishioka, ARC, October 6, 1987.

ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF): MISSION CODE SAAX017

1.0 AXAF PROGRAM AND OPERATIONS INFORMATION

1.1 AXAF Points of Contact

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Program Manager
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1.2 AXAF Objectives

The mission of the Advanced X-Ray Astrophysics Facility (AXAF) is to conduct a long-term (15-year) program of space astronomy in the X-ray region of the electromagnetic spectrum. It will also help to determine the nature of celestial objects from normal stars to quasars.

1.3 AXAF Milestone and Servicing Schedule

Launch Date:	1995 (4th quarter)
First Space Station Service:	1998 (4th quarter)
Servicing Interval:	36 months
Operational Lifetime:	15 years

1.4 AXAF Orbital Parameters

a. Free-flyer
b. 600 km altitude (release)
c. 28.5 degree inclination

2.0 AXAF PHYSICAL CHARACTERISTICS

2.1 AXAF Description

The free-flying AXAF X-ray observatory has the following major components:

a. accommodation for up to four focal plane instruments,
b. a high resolution mirror assembly,
c. solar arrays,
d. high gain antennas,
e. an aperture door, and
f. the spacecraft subsystem.

The basic AXAF configuration is illustrated in Figure AXAF-1. Detailed design will be performed during the current Phase B process.

Only one instrument will operate at a time. This process is accomplished by either rotating a carousel-like focal plane assembly or by moving the X-ray mirror assembly to focus X-rays onto the appropriate instrument.

AXAF will point its optical axis to X-ray sources on the celestial sphere and view a selected target from minutes to days, depending on the source strength and the type of science being conducted. After viewing one target, AXAF will maneuver as rapidly as possibly to acquire another.

The initial focal plane science instruments will be chosen from the following four candidates:

a. A Charge Coupled Device (CCD) Imaging Spectrometer,
b. A Microchannel Plate (MCP) High-Resolution Camera,
c. A Bragg Crystal Spectometer, and
d. A Calorimeter X-ray Spectrometer

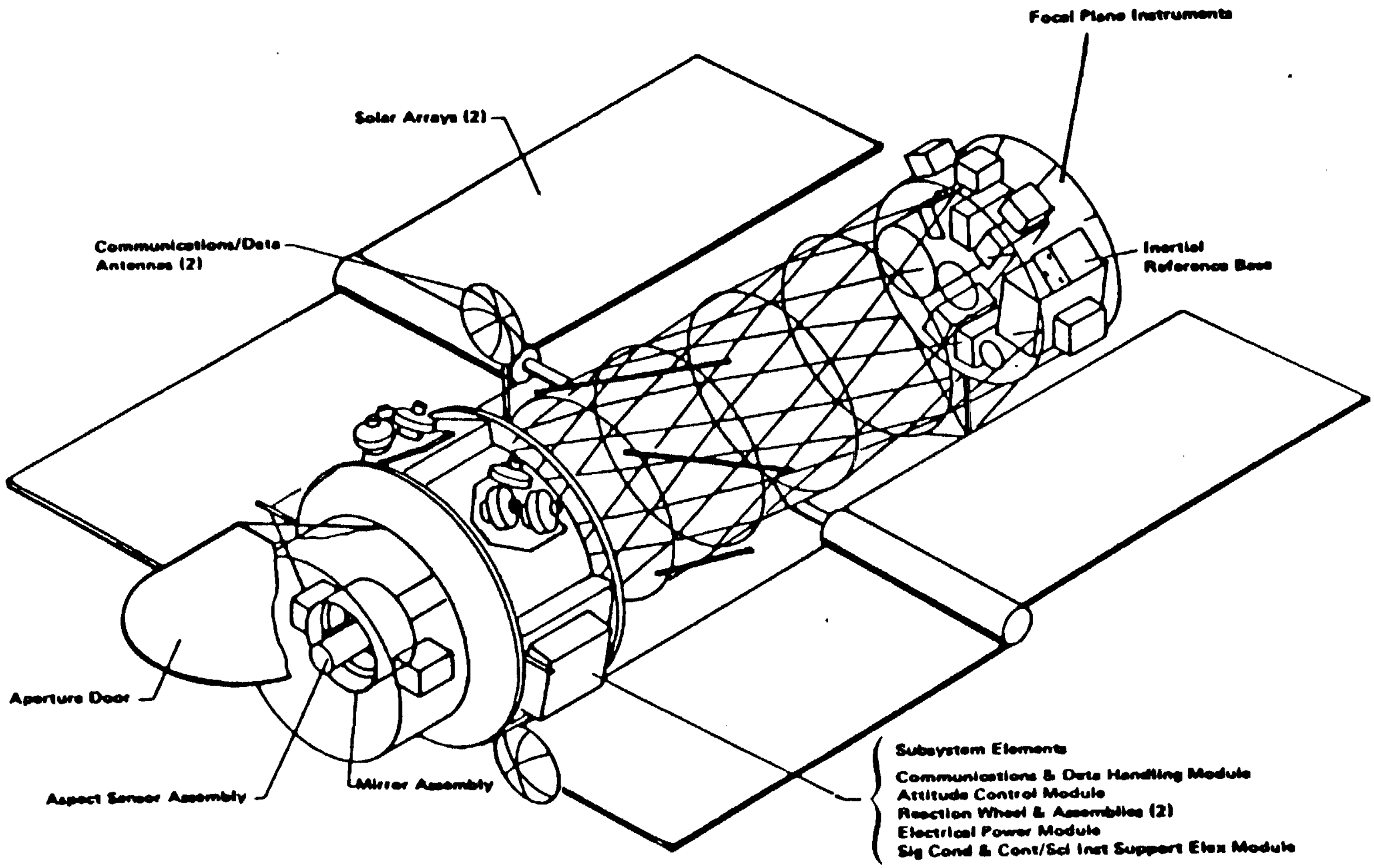

Figure AXAF-1. The Advanced X-Ray Astrophysics Facility

2.2 AXAF Physical Characteristics

a. Mass

- Dry: 13500 kg
- Wet: 13529 kg

b. Dimensions

- Length: 17.0 m
- Width: 14.3 m
- Height: 12.5 m
- Solar Arrays: 3.0 x 12.0 m
- High-Gain Antennas: 2.2 dia
- Solar Array Booms (Estimated): 2.0 m
- High-Gain Antenna Booms (Estimated): 3.0 m
- Telescope Aperture Door (Estimated): 2.0 m dia

c. Envelope

- Stowed: 15.0 x 4.6 x 5.0 m = 345 m^3
- Deployed (with aperture door open, solar arrays and high-gain antennas deployed):
  17.0 x 14.3 x 12.5 m = 3039 m^3

2.3 AXAF Moving Parts and Special Features

AXAF solar arrays, high-gain antennas, and telescope aperture door will be designed to deploy/retract automatically, with EVA override and jettison capability.

2.4 AXAF Consumables

One science instrument, the calorimeter, will have a cooling cryogen (liquid helium). No propulsion system will be aboard the AXAF spacecraft.

3.0 AXAF SERVICING INFORMATION

3.1 General Description of AXAF Servicing

AXAF will be designed for on-orbit servicing. Although the planned servicing interval is specified as three years, the actual intervals will be chosen commensurate with spacecraft performance, scientific objectives, and the OMV's capability to perform rendezvous and retrieval. Servicing dates are also constrained by the requirement to have the orbital planes of AXAF and the Space Station in alignment, an event which occurs approximately every 22 months. Contingency servicing will be performed at the STS and is not influenced by nodal alignment.

During a typical planned servicing mission, AXAF will be berthed at the Space Station for 14 days. During this time, instruments will be maintained, changed out, or upgraded. Any failed or malfunctioning subsystems will be repaired or replaced. Following verification of satisfactory operation, the OMV will be used to return AXAF to its nominal operational orbit. Prior to OMV return to the Space Station, AXAF will be fully exercised by ground command. When the AXAF Operations Control Center is satisfied with AXAF operation, the OMV will return to the Space Station.

3.2 AXAF Background

AXAF is a new facility, with instruments and spacecraft subsystems designed with servicing in mind. Several are derived from earlier instruments flown on the High Energy Astronomical Observatory (HEAO), and the spacecraft subsystems have GRO or HST heritage.

3.3 Primary Role of Space Station in Servicing AXAF

The Space Station will be used to service AXAF instruments and spacecraft modules on a scheduled basis. (Contingency servicing will be performed at the STS.) Current expectations include replacing and upgrading instruments and subsystem modules and replenishing consumables.

3.4 Primary Space Station Facilities Required for Servicing AXAF

- Trunnion sill and keel fittings for berthing
- Sun shield or shroud for thermal control
- Pressurized work area for repair of instruments and subsystem modules
- Facilities and equipment for transfer of liquid helium
- Standard EVA tool kit
- A pressurized area large enough to contain the entire spacecraft would make possible more complex repairs

3.5 Space Station Personnel Required for Servicing AXAF

Since AXAF is an unmanned facility, operational support is normally required only from the ground. Ground support will be required for checkout of AXAF during and after servicing. AXAF instrument or subsystem specialists may advise trained technicians onboard the Space Station.

3.6 Servicing Precautions for AXAF

Install covers on sensors, radiators, and instrument apertures. Vent gases when necessary. (Both the calorimeter and the Bragg Crystal Spectrometer have expendable fluids or gases which must be vented to space.) Solar shielding may be required for thermal control during servicing. Contamination control procedures must be exercised.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of AXAF

The OMV will be employed to retrieve AXAF and berth it at the Space Station. After the servicing period, the OMV will be used to deploy and boost the observatory to its proper orbit, with the possibility of contingency return. Two OMV round trips are thus required for each AXAF servicing.

4.0 AXAF SERVICING SAFETY CONSIDERATIONS

4.1 AXAF Hazardous Systems

- Cryogen (liquid helium)
- Gases for instrument operation (a mixture of argon, xenon, and carbon dioxide)
- Low-level radioactive sources for calibration of the X-ray scientific instruments are highly shielded and not hazardous to personnel
- Pyrotechnic devices

4.2 AXAF Servicing Safety Precautions

Thermal gloves are needed to protect the crew from cryogens.

5.0 AXAF SERVICING INTERFACES

5.1 AXAF Crew Convenience Features

- Two full-length longitudinal handrails
- Four full 36-degree circumferential handrails
- Circular hatch handrails
- Tether attach points
- Foot restraint sockets

5.2 AXAF Mechanical Interfaces

- FSS Berthing Pins (for FSS-equivalent available at SS)
- Sill and keel trunnions
- RMS and OMV grapple fixtures

5.3 AXAF Umbilical Interfaces

a. Power

- 28 +2/-4 VDC during servicing and operations
- 0 6 kW during storage or servicing
- 2.8 kW during operation
- 2.1 kW during checkout
- TBD kW for servicing, storage, and checkout of instruments and subsystem modules

- The AXAF umbilical connector is being designed to interface with the HST-type automatic umbilical. The HST-type umbilical requires 100 VAC (400 Hz, 0.3 A) for 3 seconds to operate.

b. Data

- 1 kbps command rate ground-to-AXAF through TDRSS and SS
- Video and voice requirements are TBD

c. Fluid

- None

5.4 AXAF RF Communication Interface

- During servicing, the link from the ground to AXAF is through TDRSS and the SS at 1 kbps
- During operation/checkout, the AXAF-to-ground link through TDRSS is 36 kbps and employs high-gain antennas

5.5 AXAF Thermal Interface

- AXAF maintains passive thermal control using heaters, so interface with SS thermal control system is not needed
- Spacecraft temperatures must be maintained between 0 and +40 degrees Centigrade during servicing and between -10 and +40 degrees Centigrade during storage

6.0 AXAF SERVICING ENVIRONMENT

6.1 AXAF Pointing/Orientation Constraints

a. Exposure to Light

- With the aperture door open, AXAF must not point within 12 degrees of the bright Earth, 45 degrees of the Sun, or 12 degrees of the Moon.

- With the aperture door closed, precautions must still be observed during retrieval, deployment, and Space Station handling prior to covering star trackers.

b. Thermal Control

The orientation of AXAF for efficient thermal control is TBD.

6.2 AXAF Contamination Concerns

- AXAF optical surfaces are sensitive to molecular contaminants and small particulates. Recent studies have indicated that possible contamination is more severe than previously anticipated. (A dust particle on a grazing incidence mirror becomes magnified such that it blocks off 100 times its own area.)
- Inert propellants only (no combustibles should be employed in the vicinity of AXAF). Protection is needed against booster activity by other payloads.
- AXAF will have a retractable cover to protect the telescope assembly from contaminants during servicing.
- High voltage instruments in AXAF must be protected from outgassing.
- Gas pressure must be less than 1.0E-05 torr prior to instrument or star tracker power-up.
- Contamination doors for aperture plates are under consideration.

6.3 AXAF Radiation Concerns

- None during AXAF inoperative periods (servicing, storage).
- Instruments are sensitive to effects of the South Atlantic Anomaly (SAA) when operating. This sensitivity may restrict checkout/test operations following servicing.
- Exposure to RF radiation is TBD.

7.0 AXAF SERVICING ACCOMMODATIONS

7.1 AXAF Equipment Access

- AXAF will be designed for on-orbit servicing and a high level of equipment access.
- AXAF will be built with TBD on-board access stations. Some potential candidates are:
  - (a) Focal Plane Instrument Station
  - (b) Subsystem Station(s)
  - (c) Forward Non-Focal Plane Instrument Station
  - (d) Aperture Door Station

The exact functions and features of the on-board access stations are TBD.

7.2 AXAF Modularity

AXAF is being designed with modularity as a goal, but actual implementation with the science instruments, AXAF subsystems, and AXAF components is TBD.

7.3 AXAF Automated Servicing

Use of in-situ servicing using an OMV with a smart front end is being contemplated. A remote automated servicing study has concluded that remote servicing of some AXAF subsystems is feasible if a suitable ORU carrier and teleoperated arm are developed. Some tasks, however, will always require EVA at the SS or the STS Orbiter.

7.4 AXAF Servicing in the Space Station Pressurized Modules

The scientific airlock must accommodate a 1.34 x 1.75 x 2.0 m module (science instrument) for pressurized servicing.

8.0 AXAF SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS-Provided	Comments	Ref.Section
ORUs (including SIs)	yes	no		9.0
Flight Support Equipment	yes	yes	FSS to be supplied	10.0
Other Equipment	no	no		10.0
Servicing Equipment Carrier(s)*	yes	no		12.0
Servicing Consumables				
Propellant(s)	no	no		11.0
container(s)	no	no		11.0
Cryogen(s)	yes	no		11.0
container(s)	yes	yes		11.0
Liquid(s)	no	no		11.0
container(s)	no	no		11.0
Gas(es)	yes	no		11.0
container(s)	yes	no		11.0
Other(s)	no	no		11.0
container(s)	no	no		11.0
Servicing Consumables Carrier(s)*	no	no		12.0

* Carriers for servicing materials are typically used during transportation in the STS Orbiter and/or during storage on the SS. A single carrier may be used.

9.0 AXAF ON-ORBIT REPLACEABLE UNITS (ORUs)

9.1 Servicing of AXAF ORUs

a. Primary

AXAF can accommodate up to four science instruments. Each of these will undergo changeout, depending on its observed durability and desired upgrades. In addition, other ORUs will be changed as necessary during the planned service missions:

- Instruments
- Objective Grating Electronics (OGE)
- Modular Power Subsystem (MPS)
- Command and Data Handling Module (CADH)
- Attitude Control System Module (ACS)
- Reaction Wheel Assembly Module (RWAM)
- High-Gain Antenna Drive Assembly (HGAD)
- High-Gain Antenna Electronics (HGAE)
- Solar Arrays
- Tape Recorders

b. Secondary

On an unplanned basis, the ORUs listed below will be replaced or repaired.

(1) Forward Group:
  - Fixed-Head Star Trackers
  - Bright Object Sensor
  - Rate Gyro Package
  - SAA Detectors

(2) Subsystems Group
  - Inertial Reference Base
  - Signal Conditioning and Control Unit (SC/CU) (Science Instrument Support Electronics)

- Aspect Camera
- Star Sensor
- Star Sensor Electronics
- Magnetic Torquer Bars

9.2 AXAF ORU Physical Characteristics

See Table AXAF-1 for mass, dimension, and quantity values for each ORU.

9.3 AXAF ORU Storage Requirements

See Table AXAF-2 for temperature ranges for some ORUs.

9.4 Other Environmental Requirements for AXAF ORUs

No additional information available.

10.0 AXAF FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 AXAF Flight Support Equipment (FSE)

A complete list of FSE is TBD. Some FSE will be for external (EVA) use and includes items such as the following :

- Grapple fixture
- EVA crew and equipment tethers
- Foot restraints
- Manipulator foot restraints (MFR)
- Ratchet wrenches and accessories
- Box end ratchet wrench
- EVA portable lights
- Portable handhold plate assembly
- Appendage jettison handle
- Electrical connector covers (on ORUs)
- Radiator cover (on ORU)
- High-Gain antenna cover
- Mission-unique tooling
- Mission-unique cabling

TABLE AXAF-1. AXAF ORU PHYSICAL CHARACTERISTICS

ORU	UNIT MASS (kg)	DIMENSIONS(m)	AXAF QUANTITY	SPARES
Planned:				
Science Instrument	115	1.34 x 1.75 x 2.0	2	0*
Science Instrument	325	1.30 x 1.30 x 2.0	2	0*
OGE	15	0.10 x 0.10 x 0.1	1	1
MPS	265	1.22 x 1.22 x 0.46	1	1
CADH	150	1.22 x 1.22 x 0.46	1	1
ACS	105	1.22 x 1.22 x 0.46	1	1
RWAM	145	1.22 x 1.22 x 0.61	1	1
HGAD	9	0.13 x 0.13 x 0.38	2	1
HGAE	2	0.05 x 0.15 x 0.18	2	1
Solar Arrays	160	0.70 x 0.70 x 4.40	2	1
Tape Recorders	6	0.15 x 0.20 x 0.20	2	1
Contingency:				
Fixed-Head Star Trackers	9	0.18 x 0.20 x 0.41	3	1
Bright Object Detector	90.5	0.05 x 0.05 x 0.08	2	1
Rate Gyro Package	17	0.25 x 0.30 x 0.33	1	1
SAA Detectors	1	0.08 x 0.08 x 0.10	2	1
Inertial Reference Base	130	0.91 x 0.91 x 0.91	1	1
SC/CU	135	0.46 x 1.22 x 1.22	1	1
Aspect Camera	23	0.15 x 0.15 x 0.36	3	1
Star Sensor	17	0.13 x 0.28 x 0.28	2	1
Star Sensor Electronics	9	0.13 x 0.51 x 0.51	2	1
Magnetic Torquer Bars	8	2.25 x 0.08 dia		

* Instrument spares will be developed as needed during the preceding three-year servicing interval.

TABLE AXAF-2. AXAF ORU STORAGE REQUIREMENTS

ORU	OPERATING TEMPERATURE (°C) MINIMUM	OPERATING TEMPERATURE (°C) MAXIMUM	STORAGE TEMPERATURE (°C) MINIMUM	STORAGE TEMPERATURE (°C) MAXIMUM
Planned:				
Science Instruments	-15	+30	-15	+40
OGE	TBD	TBD	TBD	TBD
MPS	0	+40	-10	+40
CADH	0	+40	-10	+40
ACS	-20	+40	-20	+40
RWAM	-18	+49	-23	+49
HGAD	(SPACE ENVIRONMENT)			
HGAE	(SPACE ENVIRONMENT)			
Solar Arrays	-100	+100	-110	+115
Tape Recorders	TBD	TBD	TBD	TBD
Contingency:				
Fixed-Head Star Trackers	TBD	TBD	TBD	TBD
Bright Object Detector	TBD	TBD	TBD	TBD
Rate Gyro Package	TBD	TBD	TBD	TBD
SAA Detectors	TBD	TBD	TBD	TBD
Inertial Reference Base	-10	+40	-30	+60
SC/CU	-20	+40	-20	+40
Aspect Camera	-10	+50	-20	+50
Star Sensor	TBD	TBD	TBD	TBD
Star Sensor Electronics	TBD	TBD	TBD	TBD
Magnetic Torquer Bars	(SPACE ENVIRONMENT)			

AXAF will also employ a U-shaped Flight Support System (FSS) maintenance platform provided by the Space Station. The Space Station FSS will be equivalent to the Shuttle Orbiter FSS now available.

10.2 AXAF FSE Physical Characteristics

The FSS has mass = 1900 kg and volume = 17.6 m^3, but this mass/volume is a Space Station resource and not chargeable to AXAF. The physical characteristics of the remaining FSE are TBD, but most are standard equipment. The associated mass/volume of payload-unique items is assumed to be negligible in comparison with the ORUs, carriers, and SIs transported.

10.3 AXAF FSE Storage Requirements

TBD

10.4 AXAF Miscellaneous Servicing Equipment

No information available.

11.0 AXAF SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

The liquid helium required for the calorimeter is the only consumable possibly needing replenishing. It is TBD whether this instrument will be one of the three instruments aboard AXAF or (if it is aboard) whether the liquid helium will be replenished if it is depleted. In any case, the depletion of the helium will not precipitate a contingency servicing mission. The Bragg Crystal Spectrometer contains two gas mixtures (one has 70% Ar + 20% Xe + 10% CO_2, and the other has 90% Xe and 10% CH_4). These gas mixtures will not be replenished.

11.2 Physical Characteristics

The calorimeter requires about 200 liters (i.e., 29 kg) of liquid helium at TBD pressure. Normally, the resupply dewar volume must be about 2.5 times the receiver tank volume to service a warm

facility. Replenishment of helium is considered as Space Station operations (see assumption 10 in Chapter I, section J), so the replenishment tank and cryogen are not considered part of mass up or mass down values.

11.3 Storage Requirements

TBD

12.0 CARRIERS FOR AXAF SERVICING MATERIALS

12.1 Description of Carriers

AXAF servicing materials are transported using the Orbital Replaceable Unit Carrier (ORUC) which is a Spacelab pallet modified with shelves and provisions for replacement parts. The ORUC has a mass of approximately 620 kg with dimensions of 3.4 x 4.8 x 4.0 m and volume of 66 m^3. The AXAF ORUC is shown in Figure AXAF-2.

12.2 STS/SS Carrier Interfaces

The ORUC interfaces with the STS Orbiter through the Spacelab pallet. Temporary storage of the ORUC at the Space Station is TBD. It is assumed have that the ORUC is unloaded while in the Orbiter and returned with the Orbiter to Earth.

12.3 Servicing Materials/Carrier Interfaces

TBD.

13.0 AXAF ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

- During a typical planned servicing mission, AXAF will remain at the Space Station for 14 days
- Planned servicing dates are restricted to times when AXAF and the Space Station have their orbital planes in alignment (every 22 months)

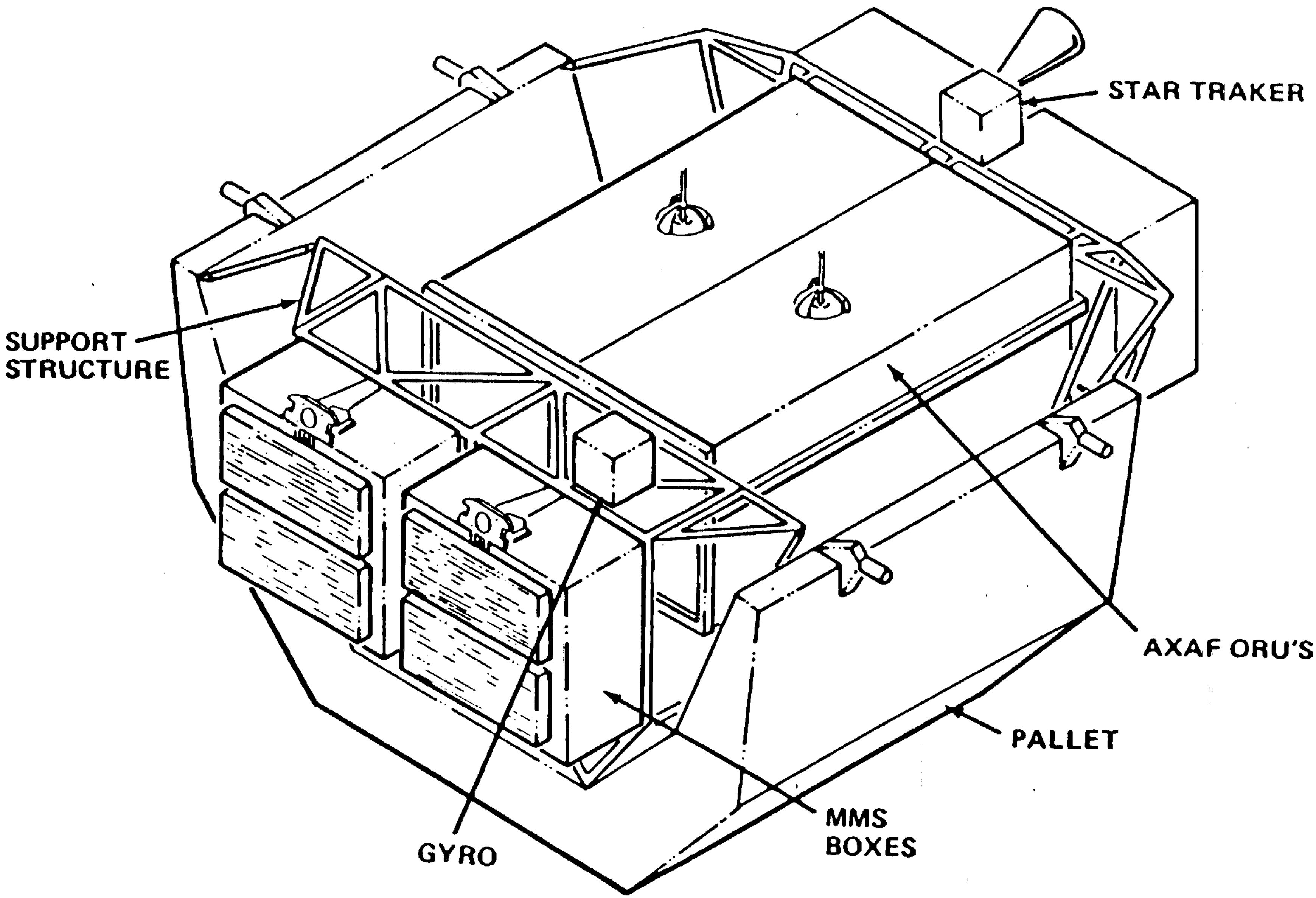

Figure AXAF-2. AXAF Orbital Replacement Unit (ORU) Carrier

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unloading servicing materials from Orbiter to SS	0:30^	0:30^	0:00^	0:30^
2. OMV berthing of AXAF	3:30^	3:30^	3:00^	2:00^

13.3 Principal Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Changeout ORUs and SIs	7:43^	11:35^	15:26^	3:52^
2. Liquid Helium Replenishment	2:18^	2:18^	4:00^	0:00^

13.4 Close-out Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. OMV deberthing of AXAF	5:30^	5:30^	3:00^	3:00^
2. Load servicing materials from SS into Orbiter	0:30^	0:30^	0:00^	0:30^

14.0 AXAF STRAWMAN SERVICING SCENARIO

14.1 AXAF Strawman Servicing Mission

The AXAF strawman servicing mission (Strawman A) is the changeout of selected ORUs and science instruments and replenishment of the liquid helium for the calorimeter. The actual ORUs and SIs changed out are TBD with each mission, but an approximate mass of 1000 kg is assumed.

14.2 AXAF Description

AXAF's solar arrays fold and its antennas are retracted during servicing. This stowed configuration has dimensions 15.0 x 4.6 x 5.0 m and a volume of 345 m^3.

14.3 Strawman Servicing Materials

a. ORUs

The following ORUs are representative of a set of components to be changed out for Strawman A:

Item	Number	Unit Mass (kg)	Volume (m^3)	Power (kW)
S.I.	1	115	4.69	TBD
S.I.	1	325	3.38	TBD
MPS	1	265	0.68	TBD
CADH	1	150	0.68	TBD
SC/CU	1	135	0.68	TBD
HGAE	1	2	0.001	TBD
Tape Recorder	1	6	0.006	TBD
SAA detectors	2	1	0.006	TBD

The total mass represented in this set is 1000 kg.

b. FSE and Miscellaneous Servicing Equipment

Actual FSE is TBD. FSE mass unique to AXAF is estimated to have mass = 0 kg and volume = 0 m^3.

c. Consumables and Containers

The calorimeter instrument requires about 200 liters (i.e., 29 kg) of liquid helium. Container mass is not included in mass up/down since replenishment from the Space Station is assumed.

d. Carriers

The AXAF ORU carrier has a mass of 620 kg and a volume of 66 m^3. It will be used to transport ORUs, SIs, and FSE.

14.4 Estimated Up/Down Mass on STS to Support AXAF Strawman Servicing

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	440	0	440
ORU(s)	560	0	560
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	1000	0	1000
Equipment Carrier(s)	620	0	620
Subtotal, Equipment Mass Up	1620	0	1620
Subtotal, Equipment Mass Down	1620	0	1620
Consumables			
Consumables*	0	0	0
Consumables Containers	0	0	0
Consumables Containers' Carriers	0	0	0
Subtotal, Consumables Mass Up	0	0	0
Subtotal, Consumables Mass Down	0	0	0
Total Mass Up	1620	0	1620
Total Mass Down	1620	0	1620

* Liquid helium is assumed to be available at the Space Station.

14.5 Estimated Up/Down Volume on STS to Support AXAF Strawman Servicing

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	8.1	0	8.1
ORU(s)	2.0	0	2.0
Unique FSE	0.0	0	0.0
Misc. Equipment	0.0	0	0.0
Equipment Subtotal	10.1	0	10.1
Equipment Carriers	66.0	0	66.0
Equipment and Carriers Subtotal	66.0	0	66.0
Consumables			
Consumables in Containers*	0	0	0
Consumables, Containers, and Carriers	0	0	0
Total Volume Up	66.0	0	66.0
Total Volume Down	66.0	0	66.0

* Liquid helium is assumed to be provided by the Space Station.

14.6 Storage on Space Station Required to Support AXAF Strawman Servicing

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	0	0	0
Volume (m^3)	0	0	0
Average Power (watts)	0	0	0
Temperature Range (^oC)	-	-	-
Temporary Storage			
Mass (kg)	1000	0	1000
Volume (m^3)	66.0	0	66.0
Average Power (watts)	600	0	600
Temperature Range (^oC)	-10 to +40	-	-10 to +40

14.7 AXAF Strawman Servicing Power Estimates

	Operational Mode (watts)		Servicing Mode (watts)	
	AVG	MAX	AVG	MAX
AXAF (Bus + Instruments)	2800	TBD	600	TBD

14.8 AXAF Strawman Servicing Times

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unloading of Servicing Material from Orbiter to SS	0:30^	0:30^	0:00^	0:30^
2. AXAF Berthing-Related Activities	3:30^	3:30^	3:00^	2:00^
3. Changeout ORUs and SIs	7:43^	11:35^	15:26^	3:52^
4. Liquid Helium Replenishment	2:18^	2:18^	4:00^	0:00^
5. AXAF Deberthing-Related Activities	5:30^	5:30^	3:00^	3:00^
6. Loading of Servicing Material from SS into Orbiter	0:30^	0:30^	0:00^	0:30^
Totals	20:01^	23:53^	25:26^	9:52^

14.9 OMV Flights in Support of AXAF Strawman Servicing Mission

Strawman Mission	Purpose of Flight	Number of Flights
Strawman A	Retrieval of AXAF	1
Strawman A	Deployment of AXAF	1

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF AXAF

15.1 AXAF Milestone and Servicing Schedule (Nominal Mission Model)

Event	Location	Date	Comment
AXAF Launch	STS/ETR	4th quarter, 1995	
1st Servicing*	SS	4th quarter, 1998	
2nd Servicing	SS	4th quarter, 2001	
3rd Servicing	SS	4th quarter, 2004	
4th Servicing	SS	4th quarter, 2007	
AXAF Mission Termination		4th quarter, 2010	

* Planned servicing intervals will be at least 36 months but are constrained by requirement for coincidence of orbital planes (every 22 months).

15.2 Summary of AXAF Mass Considerations

a. AXAF in Operational/Servicing Configurations

AXAF Mass (dry):	13500 kg
Consumables Mass:	0 kg
AXAF Mass (total):	13500 kg

b. AXAF Servicing Materials

Event	Mass Up (kg)	Mass Down (kg)
AXAF Launch	13500	
1st Servicing	1620	1620
2nd Servicing	1620	1620
3rd Servicing	1620	1620
4th Servicing	1620	1620
AXAF Mission Termination		13500
Totals	20380	20380
Servicing Totals	6480	6480

c. AXAF Servicing Storage Mass on Space Station

Calendar Year	94	95	96	97	98	99	00	01	02	03	04	05
Storage Mass (kg)												
Unpressurized	0	0	0	0	1620	0	0	1620	0	0	1620	0
Pressurized	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	1620	0	0	1620	0	0	1620	0

15.3 Summary of AXAF Volume Considerations

a. AXAF Volume

Operational Configuration:	3039 m^3
Servicing Configuration:	345 m^3
Storage/Transportation Configuration:	345 m^3

b. AXAF Servicing Volumes Up and Down in STS

Event	Volume Up (m^3)	Volume Down (m^3)
AXAF Launch	345	
1st Servicing	66	66
2nd Servicing	66	66
3rd Servicing	66	66
4th Servicing	66	66
AXAF Mission Termination		345
Totals	609	609
Servicing Totals	264	264

c. AXAF Servicing Temporary Storage Volume on Space Station

Calendar Year	94	95	96	97	98	99	00	01	02	03	04	05
Storage Volume (m^3)												
Unpressurized	0	0	0	0	66.0	0	0	66.0	0	0	66.0	0
Pressurized	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	66.0	0	0	66.0	0	0	66.0	0

15.4 Summary of AXAF Power Considerations

	AVG	MAX
Operational Power (watts)	2800	TBD
Servicing Power (watts)	600	TBD
Storage Power, Servicing Materials (watts)	600	N.A.

15.5 Summary of AXAF Servicing Time Estimates

Calendar Year	94	95	96	97	98	99	00	01	02	03	04	05	Tota
Elapsed Time (hr:min)	0	0	0	0	20:01^	0	0	20:01^	0	0	20:01^	0	60:03^
IVA Time (Crew-hr:min)	0	0	0	0	23:53^	0	0	23:53^	0	0	23:53^	0	71:39^
EVA Time (Crew-hr:min)	0	0	0	0	25:26^	0	0	25:26^	0	0	25:26^	0	76:18^
Total Crew Time (Crew-hr:min)	0	0	0	0	49:19^	0	0	49:19^	0	0	49:19^	0	147:57^
Robotics Time (hr:min)	0	0	0	0	9:52^	0	0	9:52^	0	0	9:52^	0	29:36^

15.6 Summary of OMV Flights in Support of AXAF Servicing

Calendar Year	Number of Flights	Purpose
1994	0	
1995	0	
1996	0	
1997	0	
1998	2	Retrieval and deployment
1999	0	
2000	0	
2001	2	Retrieval and deployment
2002	0	
2003	0	
2004	2	Retrieval and deployment
2005	0	

REFERENCES

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3. GSFC Satellite Servicing Workshop notes (June 9-11, 1987).
4. Mission Requirements Data Base (MRDB), NASA/JSC, January 17, 1987.
5. AXAF Phase A Study Update (July, 1985).
6. Telphone conversation with Dr. Chuck Wyman on October 2, 1987.
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COSMIC DUST COLLECTION EXPERIMENT (CDCE): MISSION CODE SAAX0112

1.0 CDCE PROGRAM AND OPERATIONS INFORMATION

1.1 CDCE Points of Contact

Dr. William Quaid,
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(713)

Mr. Dennis Grounds
Life Sciences Project Office
Code SE, NASA/JSC
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(713) 483-7313

1.2 CDCE Objective

Determine the parent objects, nature, abundance, distribution, and physical/chemical characteristics of cosmic dust particles by actually collecting such particles and measuring their trajectories.

1.3 CDCE Servicing Schedule

- Operational: 3rd quarter, 1994.
- First Service: 1st quarter, 1995.
- Servicing Interval: 180 days.
- Operational Lifetime: 5 years.

1.4 CDCE Orbital Parameters

CDCE is an attached payload.

2.0 CDCE PHYSICAL CHARACTERISTICS

2.1 CDCE Description

CDCE is a facility for the collection and retrieval of extraterrestrial material and the measurement of orbital parameters associated with the material. It is a modular system on which various types of collectors and detectors can be mounted. The initial CDCE configuration is composed of 9 1-meter square unit modules up to 100 cm deep. Evolutionary development through and beyond initial SS operation is envisioned to expand the total exposed area from 9 m^2 to 45 m^2. Two types of collection devices are planned: Type A (capture cells) and Type B (porous media). These devices will be clustered into readily exchanged on-orbit replaceable units. Both passive and electronically active arrays are planned. Power and data buses are part of the structure. Self-contained electronics collect time, direction, and velocity data upon impact. The impact data (combined with data on station orientation, position, and time) is periodically telemetered to the ground. Individual impacted cells will be replaced and returned to Earth for chemical, physical, and petrographic analysis. Cell replacement will occur initially every 180 days, with a possible subsequent increase in frequency (replacement every 90 days).

2.2 CDCE Physical Characteristics

a. Mass
- 350 kg (including infrastructure).

b. Dimensions
- 3.0 x 3.0 x 1.0 m.

c. Envelope
- 3.0 x 3.0 x 1.0 m

2.3 CDCE Moving Parts and Special Features

All or some of the CDCE collector panels may be capable of rotation.

2.4 CDCE Consumables and Limited Life Components

CDCE has no consumables.

3.0 CDCE SERVICING INFORMATION

3.1 General Description of CDCE Servicing

The CDCE servicing requirement is for periodic collection of impacted cells and packaging of these cells for return to ground. This activity will be required at 180-day intervals.

3.2 CDCE Background

The CDCE experiment has heritage from the Long Duration Exposure Facility (LDEF) but is more active because trajectory and velocity of particles are measured.

3.3 Primary Role of Space Station in Servicing CDCE

- Retrieve and replace dust collection cells.
- Prepare and ship cells to ground.
- Monitor impact data.
- Provide operational support.
- Provide site for planned and contingency servicing.

3.4 Primary Space Station Facilities Required for Servicing CDCE

- Operational support.
- Robotics harvesting and replacement of cells.

3.5 Space Station Personnel Required for Servicing CDCE

SS mission specialists will perform cell replacement and packaging. Robotics harvesting is preferred, with EVA activity backup.

3.6 Servicing Precautions for CDCE

Panels may be delicate and sensitive to contamination. Special sealed containers will be provided to be opened and resealed only during removal/replacement of ORUs. Power must be down during ORU replacement.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of CDCE

Not applicable. CDCE is an attached payload.

4.0 CDCE SERVICING SAFETY CONSIDERATIONS

4.1 CDCE Hazardous Systems

None.

4.2 CDCE Safety Requirements

No special safety requirements exist for CDCE servicing.

5.0 CDCE SERVICING INTERFACES AND RESOURCES REQUIREMENTS

5.1 CDCE Crew Convenience Features

No information available.

5.2 CDCE Mechanical Interfaces

CDCE's facility interfaces with the Payload Interface Adapter (PIA) which will be attached to a Station Interface Adapter (SIA) assembly. A sealed box containing harvested and replacement cells may be located at mid-boom. This box serves as the transportation container for cells.

5.3 CDCE Umbilical Interfaces

a. Power

- .3 kW (nominal) operational.
- .3 kW peak operational.
- Power off during servicing
- Power up for checkout.

b. Data

TBD. Experiment-generated data (impact occurence, velocity, relative trajectory) must be correlated with station position, velocity, and orientation to yield particle trajectory.

c. Fluid

Not Applicable.

5.4 CDCE RF Communication Interface

CDCE RF communications requirements in support of servicing are TBD. Operationally, correlated data is stored/processed by self-contained electronics/computer and periodically telemetered to Earth. Station to ground (and ground to station) data rate is 0.1 Kbps. Information exchange is expected about 0.1 times/day.

5.5 CDCE Thermal Interface

TBD.

6.0 CDCE SERVICING ENVIRONMENT

6.1 CDCE Pointing/Orientation Requirements

a. Exposure to Light

No information available.

b. Thermal Control

TBD. Proper thermal control is important to microprocessor operation.

6.2 CDCE Contamination Concerns

CDCE particle collection cells are delicate and extremely sensitive to contamination. Geometric shielding by neighboring structures must be minimized. These structures decrease viewing angle and constitute a source of contamination via secondary crater-ejecta originating from hypervelocity impacts. CDCE must be located in an area where contamination by particulate and gaseous species is minimized. Some particulate and gaseous contamination will occur during servicing, but the effect on CDCE will be small because of the low velocity of the impact events.

(Although low velocity impacts will not trigger destination, deposition of particles on cell surfaces creates the possibility that these low velocity particulate could be incorporated into subsequent high velocity impacts.)

6.3 CDCE Radiation Concerns

EM radiation may be a problem for delicate electronics. The trajectory sensor, for example, uses a small charge in plasma measurement.

7.0 CDCE SERVICING ACCOMMODATIONS

7.1 CDCE Equipment Access

Access to sensors, subsystems, and electronis is TBD; dust collection cells will be easily accessible.

7.2 CDCE Modularity

TBD; collection cells will be designed for snap-in/snap-out replacement.

7.3 CDCE Automated Servicing

CDCE is a candidate for advanced robotic operations. Robotic changeout of impacted cells is the preferred operational mode.

7.4 CDCE Servicing in the Space Station Pressurized Modules

None.

8.0 CDCE SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Comments	Ref. Section
ORU(s)(including SIs)	yes	no	________	9.0
Flight Support Equipment	yes	no	________	10.0
Other Equipment	no	no	________	10.0
Servicing Equipment Carrier(s)*	yes	no	________	12.0
Servicing Consumables				
Propellant(s)	no	no	________	11.0
container(s)	no	no	________	11.0
Cryogen(s)	no	no	________	11.0
container(s)	no	no	________	11.0
Liquids(s)	no	no	________	11.0
container(s)	no	no	________	11.0
Gas(es)	no	no	________	11.0
container(s)	no	no	________	11.0
Other(s)	no	no	________	11.0
container(s)	no	no	________	11.0
Servicing Consumables Carrier(s)*	no	no	________	12.0

*Carriers for servicing materials are typically used during transportation in STS Orbiter and/or during storage on SS. A single carrier may be used.

9.0 CDCE ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of CDCE ORUs

a. Primary
Dust collection cells which have received impacts are serviced every 180 days. This activity is the only planned servicing.

b. Secondary
Replacement sensors and electronics packages will be serviced on a contingency basis.

9.2 CDCE ORU Physical Characteristics
Each collection cell has a mass of about 0.4 kg and dimensions of 0.2 x 0.2 x 0.3 m. There are 225 such cells, each with a volume of .012 m^3. These 225 cells are distributed over 9 1-meter square modules, with each module composed of 25 cells.

9.3 CDCE ORU Storage Requirements
An STS-compatible carrier will remain on the station to store harvested cells and serve as a source for replacement cells. It may be located mid-boom and will be exchanged a second carrier containing replacement cells every 180 days.

9.4 Other Environmental Requirements for CDCE ORUs
Contamination by gases (from the shuttle and from other spacecraft) is of particular concern.

10.0 CDCE FLIGHT SUPPORT EQUIPMENT (FSE) AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 CDCE Flight Support Equipment (FSE)
TBD. The collection cell container is described under "carriers in Section 12 below.

10.2 CDCE FSE Physical Characteristics

TBD.

10.3 CDCE FSE Storage Requirements

TBD.

10.4 Miscellaneous Servicing Equipment

TBD.

11.0 CDCE SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

CDCE has no consumables.

11.2 Physical Characteristics

Not applicable.

11.3 Storage Requirements

Not applicable.

12.0 CARRIERS FOR CDCE SERVICING MATERIALS

12.1 Description of Carriers

The collection cell containers have mass = 20 kg and volume = 1 m^3. Dimensions are TBD. At any given time, one container will be on the ground and the other will be on the SS.

12.2 STS and SS Carrier Interfaces

A container transporting fresh collection cells will be removed from STS and exchanged with the container currently on the station. The removed container will then become the ground-based container.

12.3 Servicing Materials/Carrier Interfaces

Cells are removed from the container (and harvested cells are replaced) at the CDCE site on an as needed contingency basis during CDCE operation. The container of harvested cells is replaced every 180 days.

13.0 CDCE ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

- Power must be off during panel replacement.
- Fully robotic servicing is the nominal, preferred mode of servicing. EVA time estimates have been included for information on possible backup activity.

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
Transport Servicing Material To CDCE From Storage	1:30^	1:30^	3:00^	1:30^

13.3 Principal Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
ORU Changeout	0:50^	0:75^	1:40^	0:17^

13.4 Close-out Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
Transport Servicing Material from CDCE	1:30^	1:30^	3:00^	1:30^

14.0 CDCE STRAWMAN SERVICING SCENARIO

14.1 CDCE Strawman Servicing Mission

The only planned servicing mission (strawman A) for CDCE is the replacement of impacted cells every 180 days. This replacement is realized by the exchange of cell containers. The cell container housing both fresh and harvested cells replaced by a similar container housing new cells. 100 cells (approximately half of all the cells) are exchanged in this way every 180 days.

14.2 CDCE Description

The CDCE servicing configuration is identical to its operational configuration. Its mass is 350 kg, its volume is 9 m^3, and its dimensions are 3 x 3 x 1 m. Nine one-meter modules contain 25 cells each.

14.3 STRAWMAN Servicing Materials

a. ORUs

Replacement panels are brought up in groups of 100 in the unpressurized logistics carrier.

Item	Number	Mass (kg)	Volume(m^3)	Power (kW)
Panels	100	20	0.5	TBD

b. FSE and Miscellaneous Servicing Equipment

TBD. Assumed to be negligible.

c. Consumables and Containers

Not applicable. CDCE has no consumables.

d. Carriers

The capture cell container has a mass of 20 kg and a volume of 1 m^3 (filled or empty).

14.4 Estimated Up/Down Mass on STS to Support CDCE Strawman Servicing*

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	0	0	0
ORU(s)	20	0	20
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	20	0	20
Equipment Carrier(s)	20	0	20
Subtotal, Equipment Mass Up	40	0	40
Subtotal, Equipment Mass Down	40	0	40
Consumables			
Consumables	0	0	0
Consumables Containers	0	0	0
Consumables Containers Carriers	0	0	0
Subtotal, Consumables Mass Up	0	0	0
Subtotal, Consumables Mass Down	0	0	0
Total Mass Up	40	0	40
Total Mass Down	40	0	40

* Servicing materials are transported to and from SS via the unpressurized logistics carrier as part of SS operations.

14.5 Estimated STS Up/Down Volume to Support CDCE Strawman Servicing

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	0	0	0
ORU(s)	0.5	0	0.5
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	0.5	0	0.5
Equipment Carrier(s)	1.0	0	1.0
Equipment and Carriers Subtotal	1.0	0	1.0
Consumables			
Consumables in Containers	0	0	0
Consumables, Containers, and Carriers	0	0	0
Total Volume Up	1.0	0	1.0
Total Volume Down	1.0	0	1.0

* Servicing materials are transported to and from SS via the unpressurized logistics carrier as part of SS operations.

14.6 Storage on Space Station Required to Support Strawman CDCE Servicing

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	40	0	40
Volume (m^3)	1	0	1
Average Power (watts)	TBD	0	TBD
Temperature Range (°C)	TBD	-	TBD
Temporary Storage			
Mass (kg)	0	0	0
Volume (m^3)	0	0	0
Average Power (watts)	0	0	0
Temperature Range (°C)	-	-	-

14.7 CDCE Strawman Servicing Power Estimates

	Operational Mode (Watts)		Servicing Mode (Watts)	
	AVG	MAX	AVG	MAX
CDCE (Bus + Instruments)	300	300	0	0

14.8 CDCE Strawman Servicing Times*

Servicing Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotic Time (hr:min)
1. Transport Servicing Material To CDCE	1:30^	1:30^	3:00^	1:30^
2. ORU Changeout	0:50^	0:75^	1:40^	0:25^
3. Transport Servicing Material from CDCE	1:30^	1:30^	3:00^	1:30^
TOTALS	3:50^	4:15^	7:40^	3:25^

* EVA estimates are provided for information only. Robotics is the preferred servicing method, with EVA backup.

14.9 OMV Flights in Support of CDCE Strawman Servicing Mission

Not Applicable.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF CDCE

15.1 CDCE Milestones and Servicing Schedule (Nominal Mission Model)

Event	Location	Date	Comment
Payload Launch	STS/KSC	3rd quarter, 1994	
1st Servicing	SS	1st quarter, 1995	Strawman A
2nd Servicing	SS	3rd quarter, 1995	Strawman A
3rd Servicing	SS	1st quarter, 1996	Strawman A
4th Servicing	SS	3rd quarter, 1996	Strawman A
5th Servicing	SS	1st quarter, 1997	Strawman A
6th Servicing	SS	3rd quarter, 1997	Strawman A
7th Servicing	SS	1st quarter, 1998	Strawman A
8th Servicing	SS	3rd quarter, 1998	Strawman A
9th Servicing	SS	1st quarter, 1999	Strawman A
Payload Mission Termination *		3rd quarter, 1999	

* At termination, CDCE may expand to the next phase of its evolutionary development.

15.2 Summary of CDCE Mass Considerations

a. CDCE Mass (Operational and During Servicing)

Oper CDCE Mass (dry):	350 kg	Servicing CDCE Mass (dry):	350 kg
Oper Consumables Mass:	0 kg	Servicing Consumables Mass:	0 kg
Oper CDCE Mass (total):	350 kg	Servicing CDCE Mass(total):	350 kg

b. CDCE Servicing Mass Up and Down in STS

Event	Mass Up (kg)	Mass Down (kg)
Launch	350	
1st Servicing	40	40
2nd Servicing	40	40
3rd Servicing	40	40
4th Servicing	40	40
5th Servicing	40	40
6th Servicing	40	40
7th Servicing	40	40
8th Servicing	40	40
9th Servicing	40	40
Termination*		350
Totals	710	710
Servicing Totals	360	360

* At termination, CDCE may expand to the next phase of its evolutionary development instead of returning to Earth.

c. CDCE Servicing Storage Mass on Space Station*

Calendar Year	94	95	96	97	98	99	00	01	02	03	04	05
Storage Mass (kg)												
Unpressurized	0	40	40	40	40	40	0	0	0	0	0	0
Pressurized	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	40	40	40	40	40	0	0	0	0	0	0

15.3 Summary of CDCE Volume Considerations

a. CDCE Volume

Operational Configuration: 9 m^3
Servicing Configuration: 9 m^3
Storage/Transportation Configuration: 2 m^3
(A collapsible structure is under consideration)

b. CDCE Servicing Volumes Up and Down in STS

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	4*	
1st Servicing	1	1
2nd Servicing	1	1
3rd Servicing	1	1
4th Servicing	1	1
5th Servicing	1	1
6th Servicing	1	1
7th Servicing	1	1
8th Servicing	1	1
9th Servicing	1	1
Payload Mission Termination		4**
Totals	13	13
Servicing Totals	9	9

*At termination, CDCE may expand to the next phase of its evolutionary development.
**Volume up/down includes the collapsed facility (2 m^3) and the instruments (2 m^3).

c. CDCE Servicing Storage Volume on Space Station

Calendar Year	94	95	96	97	98	99*	00	01	01	03	04	05
Storage Volume (m^3)												
Unpressurized	0	1	1	1	1	1	0	0	0	0	0	0
Pressurized	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	1	1	1	1	1	0	0	0	0	0	0

*At termination, CDCE may be expanded to the next phase of its evolutionary development.

15.4 Summary of CDCE Power Considerations

	AVG	MAX
Operational Power (watts)	300	300
Servicing Power (watts)	TBD	TBD
Storage Power, Servicing Materials (watts)	TBD	TBD

15.5 Summary of CDCE Servicing Time Estimates*

Calendar Year	94	95	96	97	98	99	00	01	02	03	04	05	Total
Elapsed Time (hr:min)	0	7:40	7:40	7:40	7:40	3:50	0	0	0	0	0	0	34:30
IVA Time (Crew-hr:min)	0	8:30	8:30	8:30	8:30	4:15	0	0	0	0	0	0	38:15
EVA Time (Crew-hr:min)	0	15:20	15:20	15:20	15:20	7:40	0	0	0	0	0	0	69:00
Total Crew Time (hr:min)	0	23:50	23:50	23:50	23:50	11:55	0	0	0	0	0	0	107:15
Robotics Time (hr:min)	0	6:50	6:50	6:50	6:50	3:25	0	0	0	0	0	0	30:45

* At termination, CDCE may expand to the next phase of its evolutionary development. EVA estimates are provided for information only. Robotics is the preferred serving method, with EVA backup.

15.6 Summary of OMV Flights in Support of CDCE Servicing

Not applicable. CDCE is an attached payload.

REFERENCES

1. Interview with Dr. William Quaid, NASA/HQ, August 5, 1987.

2. Telephone conversation with Mr. Frederick Horz, NASA/JSC, September, 1987.

3. Mission Requirements Database (MRDB), January, 1987.

COSMIC RAY NUCLEI EXPERIMENT (CRNE): MISSION CODE SAAX0001

1.0 CRNE PROGRAM AND OPERATIONS INFORMATION

1.1 CRNE Points of Contact

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1.2 CRNE Objectives

- Study the energy spectra of primary cosmic ray nuclei in order to understand the mechanisms of cosmic ray acceleration.
- Search for changes in the elemental composition at extremely high energies (approx. 10^{15} eV) that might be related to the acceleration of these particles and their escape from the galaxy.
- Study the propagation of cosmic rays through the galaxy and their interactions with the interstellar medium through measurements of secondary, spallation produced nuclei, over a wide range of energies.

1.3 CRNE Milestone and Servicing Schedule

Launch Date: 3rd quarter, 1994.
First Space Station Service: Not applicable.
Servicing Interval: Not applicable.
Operational Lifetime: 2 years.

1.4 CRNE Orbital Parameters

CRNE is a Space Station anti-earth pointing attached payload. While the orbit is not critical, lower altitude and inclination are preferable to minimize the time spent in radiation belts and the South Atlantic Anomaly (SAA).

2.0 CRNE PHYSICAL CHARACTERISTICS

2.1 CRNE Description

The CRNE instrument is an electronic counter telescope consisting of two plastic scintillation counters, two gas Cerenkov counters, and a Transition Radiation Detector (TRD) system of six radiators, each followed by a Multi-Wire Proportional Counter (MWPC). No equipment repair/exchange servicing is planned because the instrument is built inside a pressurized container. (See Figure CRNE-1.)

2.2 CRNE Physical Characteristics

a. Mass
   - Dry: 2520 kg
   - Wet: N.A.

b. Dimensions
   - 2.7 x 3.7 x 4.8 m

c. Envelope
   - Stowed: 50 m^3
   - Deployed: 50 m^3

2.3 CRNE Moving Parts and Special Features

None.

2.4 CRNE Consumables

None.

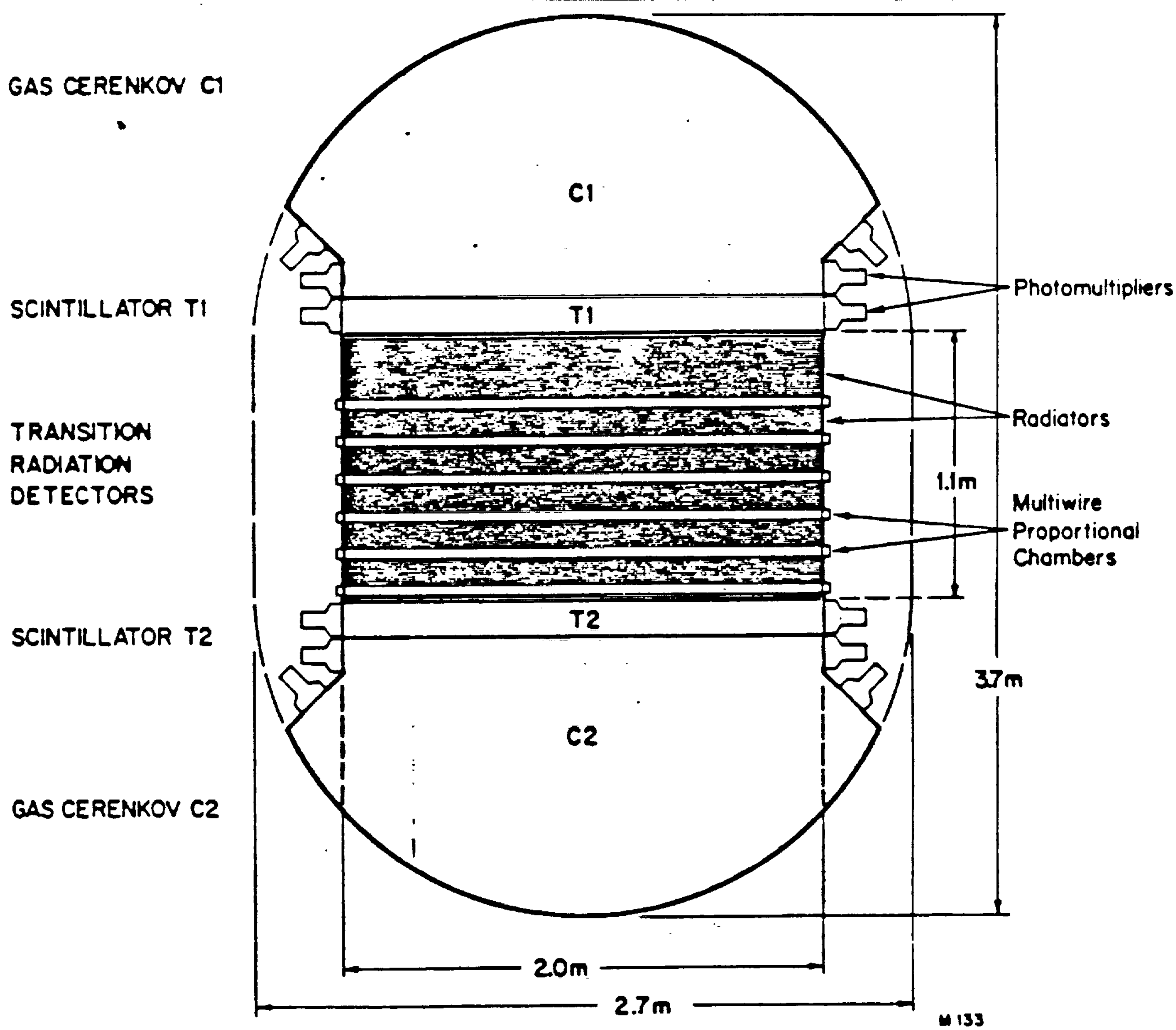

Figure CRNE-1. The Cosmic Ray Nuclei Experiment

3.0 CRNE SERVICING INFORMATION

3.1 General Description of CRNE Servicing

CRNE is a sealed and pressurized experiment and can only be accessed in a pressurized environment. Therefore, no maintenance is planned during SS operation.

3.2 CRNE Background

CRNE is an existing experiment that has flown on Spacelab 2. It was developed by the University of Chicago in conjunction with NASA. With minor modifications, CRNE can take advantage of the longer mission duration provided by SS.

3.3 Primary Role of Space Station in Servicing CRNE

SS operations include only the attachment of CRNE to the SS at start of operation and detachment at experiment termination. These activities are considered to be operational. Thus, CRNE requires no SS-based servicing.

3.4 Primary Space Station Facilities Required for Servicing CRNE

Not applicable.

3.5 Space Station Personnel Required for Servicing CRNE

Not applicable.

3.6 Servicing Precautions for CRNE

CRNE should not be under power during attachment/detachment, which are operational activities rather than servicing.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of CRNE

Not applicable.

4.0 CRNE SERVICING SAFETY CONSIDERATIONS

4.1 CRNE Hazardous Systems

CRNE contains pressurized gases.

4.2 CRNE Servicing Safety Precautions

None specified.

5.0 CRNE SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 CRNE Crew Convenience Features

Handholds and gripping point for manual installation and detachment.

5.2 CRNE Mechanical Interfaces

None specified. CRNE is an existing facility which currently uses sill and keel trunnions for attachment to the STS payload bay.

5.3 CRNE Umbilical Interfaces

a. Power
- Servicing rate is TBD.

  Operational rate:
- 28 V DC (unregulated)
- 0 kW during installation/detachment and storage
- 0.4 kW during operation

b. Data

  Operational rate:
- 1 kbps CMD rate
- 100 kbps Engineering and Science data rate

c. Fluid
- Cooling fluid loop which taps into the SS cooling system.

5.4 CRNE RF Communications Interface

Video and voice to ground required during installation/detachment.

5.5 CRNE Thermal Interface

- Temperature must be maintained between -10 and 40 degrees Celsius during installation/detachment or storage.

- CRNE uses an external closed-loop fluid cooling system which taps (via a heat exchanger) its cooling potential from the SS cooling fluid. Operational requirements for this CRNE cooling fluid demand a 0 to 30 degree Celcius fluid temperature range.

6.0 CRNE SERVICING ENVIRONMENT

6.1 CRNE Pointing/Orientation Constraints

CRNE points in the anti-earth direction. No part of the SS should be in CRNE's field of view, during nominal operation. No servicing constraints have been identified.

6.2 CRNE Contamination Concerns

None specified.

6.3 CRNE Radiation Concerns

Avoid checkout, calibration and test during SAA. CRNE will automatically stop instrument operation during passage through the South Atlantic Anomaly (SAA).

7.0 CRNE SERVICING ACCOMMODATIONS

7.1 CRNE Equipment Access

Equipment access is not specified; CRNE requires no SS servicing.

7.2 CRNE Modularity

The cooling system pump motor, even though not planned as an ORU, is designed in a modular fashion. Service on this motor would occur only on a contingency basis.

7.3 CRNE Automated Servicing

Not applicable.

7.4 CRNE Servicing in the Space Station Pressurized Modules

None required.

8.0 CRNE SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Ref. Section
ORUs (including SIs)	No	No	9.0
Flight Support Equipment	No	No	10.0
Other Equipment	No	No	10.0
Servicing Equipment Carrier(s)	No	No	12.0
Servicing Consumables			
Propellant(s)	No	No	11.0
container(s)	No	No	11.0
Cryogen(s)	No	No	11.0
container(s)	No	No	11.0
Liquids(s)	No	No	11.0
container(s)	No	No	11.0
Gas(es)	No	No	11.0
container(s)	No	No	11.0
Other(s)	No	No	11.0
container(s)	No	No	11.0
Servicing Consumables Carrier(s)	No	No	12.0

9.0 CRNE ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of CRNE ORUs

CRNE has no planned servicing. The replacement of the cooling system pump motor is feasible if required. Because this equipment would be serviced only on a contingency basis, this pump motor is not considered to be an ORU.

9.2 CRNE ORU Physical Characteristics

Not applicable.

9.3 CRNE ORU Storage Requirements

Not applicable.

9.4 Other Environmental Requirements for CRNE ORUs

Not applicable.

10.0 CRNE FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 CRNE Flight Support Equipment (FSE)

CRNE requires no SS-based servicing.

10.2 CRNE FSE Physical Characteristics

Not applicable.

10.3 CRNE FSE Storage Requirements

Not applicable.

10.4 Miscellaneous Servicing Equipment

Not applicable.

11.0 CRNE SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

CRNE is a sealed and pressurized experiment. Operational activities involve the attachment and detachment of the experiment to the SS. No servicing activities are required. CRNE requires no consumable refurbishment.

11.2 Physical Characteristics

Not applicable.

11.3 Storage Requirements

Not applicable.

12.0 CARRIERS FOR CRNE SERVICING MATERIALS

12.1 Description of Carrier

Not applicable.

12.2 STS and SS Carrier Interfaces

Not applicable.

12.3 Servicing Materials/Carrier Interfaces

Not applicable.

13.0 CRNE ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

CRNE has no planned servicing missions. Contingency servicing missions are not considered in this document.

13.2 Preparatory Servicing Time Estimates

Not applicable.

13.3 Principal Servicing Time Estimates

Not applicable.

13.4 Close-Out Servicing Time Estimate

Not applicable.

14.0 CRNE STRAWMAN SERVICING SCENARIO

14.1 CRNE Strawman Servicing Mission

CRNE requires no servicing.

14.2 CRNE Description

CRNE is a sealed and pressurized experiment with a total mass of 2520 kg and an envelope of 50 m^3.

14.3 Strawman Servicing Materials

a. ORUs
- CRNE has no planned ORUs.

b. FSE and Miscellaneous Equipment
- None required.

c. Consumables and Containers
- Not applicable.

d. Carriers
- None required.

14.4 Estimated Up/Down Mass on STS to Support CRNE Strawman Servicing

Not applicable.

14.5 Estimated Up/Down Volume on STS to Support CRNE Strawman Servicing

Not applicable.

14.6 Storage on Space Station Required to Support Strawman CRNE Servicing

Not applicable.

14.7 CRNE Strawman Servicing Power Estimate

Not applicable.

14.8 CRNE Strawman Servicing Times

Not applicable.

14.9 OMV Flights in Support of CRNE Strawman Servicing Mission

Not applicable.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF CRNE

15.1 CRNE Milestone and Servicing Schedule

Event	Location	Date
Launch	KSC	3rd quarter, 1992
Termination		3rd quarter, 1994

15.2 Summary of CRNE Mass Considerations

a. CRNE Mass in Operational/Servicing Configurations

	Operational
CRNE (dry)	2520 kg
Consumables	0 kg
Total	2520 kg

b. CRNE Mass Up and Down in STS

Event	Mass Up	Mass Down
Launch	2520 kg	0 kg
Termination	-	2520 kg
Totals	2520 kg	2520 kg
Servicing Totals	0 kg	0 kg

c. CRNE Servicing Storage Mass on Space Station

Not applicable.

15.3 Summary of CRNE Volume Considerations

a. CRNE Volume

Operational Configuration:	50 m^3
Servicing Configuration:	50 m^3
Storage/Transportation Configuration:	50 m^3

b. CRNE Servicing Volumes Up and Down in STS

Event	Volume Up	Volume Down
Launch	50 m^3	0 m^3
Termination	0 m^3	50 m^3
Totals	50 m^3	50 m^3
Servicing Totals	0 m^3	0 m^3

c. CRNE Servicing Storage Volume on Space Station

Not applicable.

15.4 Summary of CRNE Power Considerations

	Average	Maximum
CRNE Operational Power (kW)	0.4	TBD
CRNE Servicing Power (kW)	N.A.	N.A.
Storage Power, Servicing Materials (kW)	N.A.	N.A.

15.5 Summary of CRNE Servicing Times

Not applicable.

15.6 Summary of OMV Flights in Support of CRNE Servicing

Not applicable.

REFERENCES

1. Mission Requirements Database, January, 1987, NASA/JSC.

2. Telephone conversation with Dr. Jacques L'Heureux, University of Chicago/LASR, May 27, 1987.

Earth Observing System (Eos) Mission Code SAAX0202

1.0 Eos PROGRAM AND OPERATIONS INFORMATION

1.1 Eos Points of Contact

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1.2 Eos Objectives

The Eos mission is to obtain detailed physical, chemical, and biological knowledge in long-term studies of the solid earth, atmosphere, and ice caps. The Eos program, through international cooperation, consists of four polar orbiting platforms (POP): two NASA platforms (NPOP-1, NPOP-2), a European platform (EPOP-1), and a Japanese platform (JPOP-1). The information presented here reflects the requirements of the two NASA platforms only, i.e., NPOP-1 and NPOP-2, although programmatic information for EPOP-1 and JPOP-1 will be included as required.

1.3 Eos Servicing Schedule

Launch Data:	NPOP-1	4th quarter, 1995
	NPOP-2	2nd quarter, 1997 (earliest date possible)
First Service Mission:	NPOP-1	4th quarter, 1998
	NPOP-2	2nd quarter, 2000
Servicing Interval:	3 years each platform	
Operational Lifetime:	15 years each platform	

All polar platform servicing missions require WTR launches. The 2nd quarter of 1997 is the earliest possible launch date for the 2nd NASA platform. NPOP-1 and NPOP-2 are planning a servicing interval of 3 years for each platform. EPOP-1 is planned for launch in the 1st quarter of 1997 (after NPOP-1 but before NPOP-2) with a 3 year service interval. JPOP-1 is planned for launch after NPOP-2, sometime in 1998.

1.4 Eos Orbital Parameters

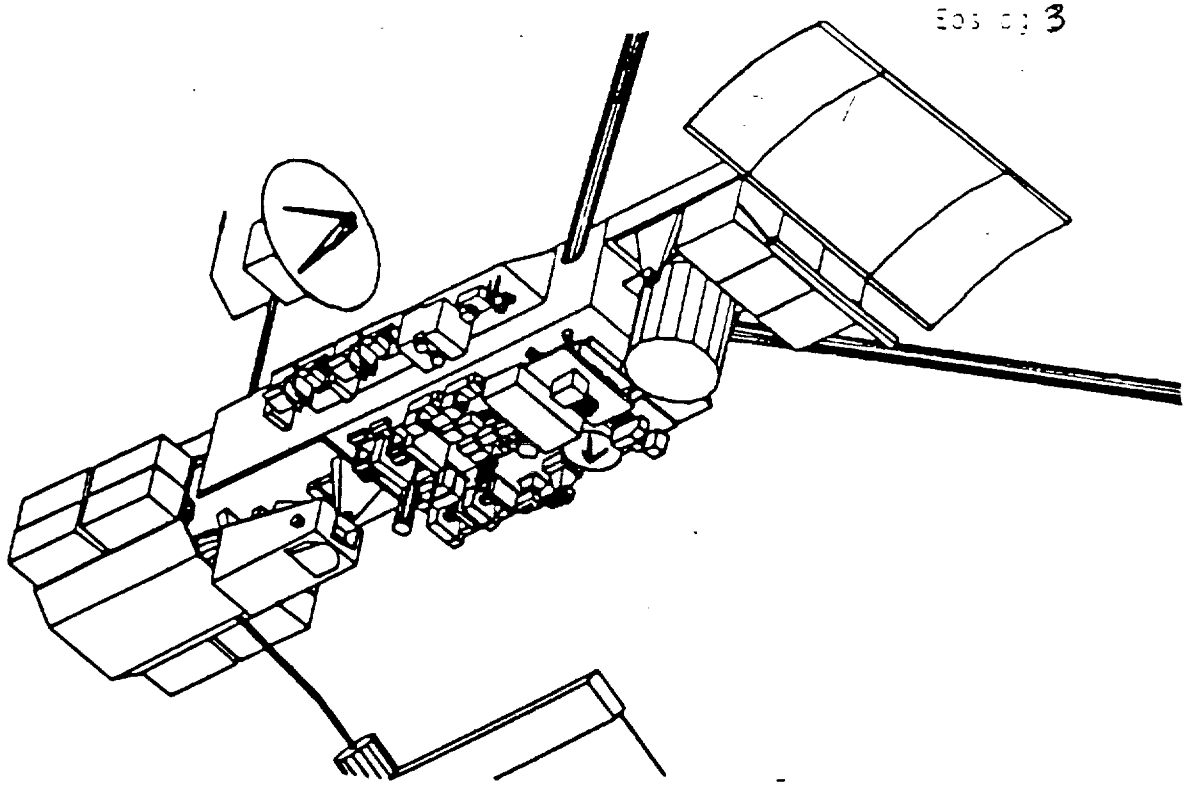
	NPOP-1	NPOP-2	EPOP-1	JPOP-1
Altitude (km)	824	824	824	800
Inclination (deg)	98.7	98.7	98.7	98.7
Crossing time	1:30 PM	1:30 PM	9:30 AM	10-12 Noon
Direction	Ascending	Ascending	Descending	TBD

Note: Orbits are circular, sun-synchronous and exact inclination values are dependent on altitude.

2.0 Eos PHYSICAL CHARACTERISTICS

2.1 Eos Description

Eos will consist of a synergistic mix of instruments mounted on four platforms in polar low earth orbit. The list of Eos instruments is shown in Table Eos-1. This list includes the NOAA, European, and Japanese instruments which will share the Eos polar platforms. The specific instrument sets for each platform are still being studied by the scientific community. Each platform is a Space Station Program element. The platforms will supply power, communications, attitude control, and pointing capability to the Eos payloads. A description of the Space Station Polar Platform element can be found in the Space Station's Baseline Configuration Document, JSC 30255. Representative configurations of the Eos polar platforms are shown in Figures Eos-1 and 2.



.Figure Eos-1. Representative Configuration - Eos Project Study Design

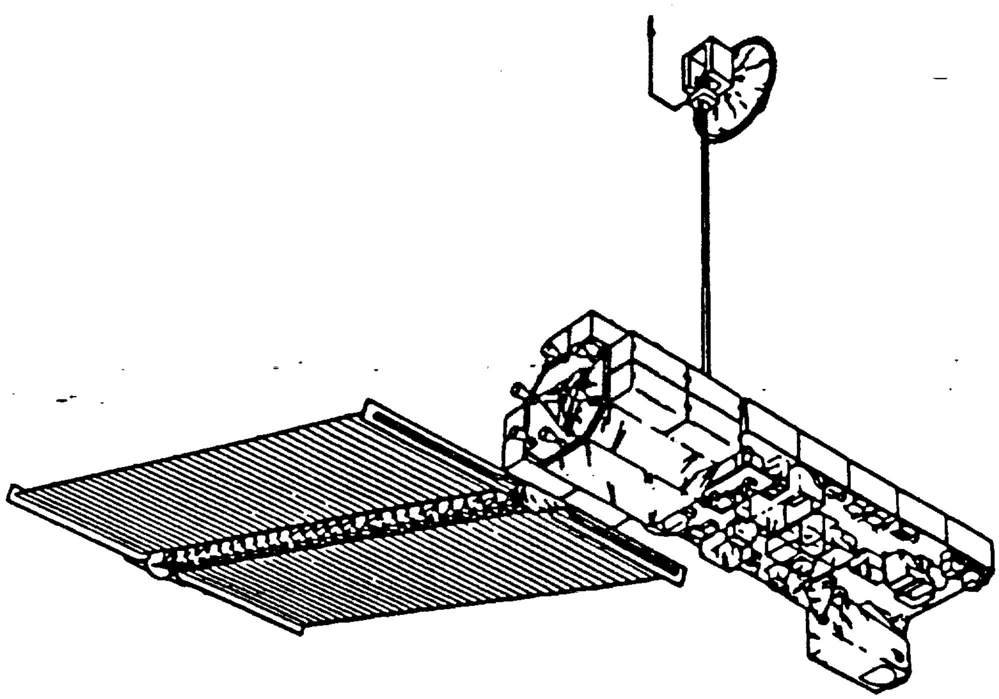


Figure Eos-2. Representative Configuration - WP-3 Study Design

2.2 Eos Physical Characteristics

Table Eos-1 contains estimates of Eos instrument masses and dimensions. These are preliminary estimates provided by the Eos program for planning purposes; they are not final values and will be updated as instrument definitions are improved. The official reference defining the mission and instrument requirements is the Space Station's Mission Requirements Data Base (MRDB).

2.3 Eos Moving Parts and Special Features

Most Eos instruments have moving parts. Many have mechanically scanned detectors and some have rotating telescopes or antennas. Instruments with cooled detectors and optics employ mechanical refrigerators or radiating coolers. Table Eos-1 contains brief descriptions of each Eos instrument.

2.4 Eos Consumables

a. Consumables

None identified at this time. This may change however, as some instruments with cooled detectors and optics may ultimately need to be cooled cryogenically.

b. Limited Life Components

The operational lifetime of the mechanical refrigerators is currently unknown. These items may require replacement as often as every two years. Instruments using laser systems or mechanical scanners will also require parts changeout or refurbishment on a TBD basis. Eos instruments are being designed for removal and replacement, or for electronics/subsystems changeout. Subsystems and components are being designed to last from service interval to service interval. Since Eos will be operational for up to fifteen years, preventive maintenance will require that instrument support equipment and subsystems be changed out on a regular basis.

Table Eos-1. Eos INSTRUMENT PHYSICAL CHARACTERISTICS AND DESCRIPTION

MISSION CODE	INSTRUMENT	DIMENSIONS (m)	MASS (kg)	DESCRIPTION
SAAX 0208	MODIS-T	0.25 x 0.30 x 0.60	100	Composed of optical telescope assemblies, moving scan mirrors, mechanical refrigerator for cooled IR detectors and optics, and electronics boxes.
SAAX 0209	HIRIS	1.90 x 2.00 x 2.81	1080	Composed of articulated optical telescope assembly (673 kg) and fixed support structure and electronics boxes (407 kg).
SAAX 0210	AMSR	4.40 x 6.00 x 7.70	320	Composed of a rotating 4x6 meter scan antenna (240 kg), with support structure, radiometer support subsystems, and electronics boxes (80 kg). The antenna mechanism rotates at 30 rpm and will be momentum compensated to limit disturbance torques transmitted to the platform.
SAAX 0212	SAR: ANT SAR: ELEC SAR: MISC	0.01 x 4.07 x 20.1 0.40 x 1.00 x 1.00	1380 360 200	Composed of a gimbaled rectangular antenna, antenna boom, support structure, electronics boxes, and cooling system.
SAAX 0213	ALT	0.67 x 1.00 x 1.00	180	Composed of a 1-meter diameter antenna and electronics boxes.
SAAX 0214	SCAT: ANT SCAT: ELEC	0.13 x 0.13 x 3.68 0.25 x 0.87 x 1.40	60 120	Composed of six 3.68 m antenna rods which project from one side of the SCAT electronics box. The antennae may be mounted remotely from the electronics.

Table Eos-1. Eos INSTRUMENT PHYSICAL CHARACTERISTICS AND DESCRIPTION (CONT'D)

MISSION CODE	INSTRUMENT	DIMENSIONS (m)	MASS (kg)	DESCRIPTION
SAAX 0215	CR	0.55 x 0.67 x 1.00	100	Composed of small optical system with integral electronics
SAAX 0216	ERBI	0.46 x 0.50 x 0.62	32	Composed of a single unit containing four Earth-viewing radiation sensors and and integral electronics. Simultaneously samples the solar flux density.
SAAX 0219	SUSIM	0.25 x 0.80 x 1.23	112	Composed of four modules containing scanning instruments and electronics.
SAAX 0230	F/P INT	0.88 x 1.03 x 1.18	115	Composed oof a gimballed 0.25 m diameter telescope 0.61 m long, a triple Etalon optical interferometer, and support electronic boxes.
SAAX 0232	MLS	1.25 x 1.65 x 3.47	400	Composed of a scanning antenna with five microwave radiometers and support electronic boxes.
SAAX 0233	SUBMM	0.50 x 0.59 x 1.00	500	Composed of a scanning antenna system, multiple radiometers using cooled detectors, and support electronic boxes.
SAAX 0235	IR RAD	0.65 x 1.33 x 2.00	150	Composed of an optical telescope, cooled detectors, and support electronics boxes.

Table Eos-1. Eos INSTRUMENT PHYSICAL CHARACTERISTICS AND DESCRIPTION (CONT'D)

MISSION CODE	INSTRUMENT	DIMENSIONS (m)	MASS (kg)	DESCRIPTION
SAAX 0236	LAWS	3.61 x 3.82 dia	800	Composed of a rotating telescope 3 rpm, 365 kgm, laser system, and support electronics boxes. The telescope is canted at 53 degrees to the rotation axis and rotates continuously; a counter-rotating momentum wheel is included in the system.
SAAX 0239	MODIS-N	0.80 x 0.80 x 1.60	200	Composed of optical telescope assemblies, scan mirrors, mechanical refrigerator or radiant cooler for cooled IR detectors and optics, and electronics boxes.
SAAX 0241	GLRS	0.91 x 1.12 x 1.92	340	Composed of a TBD-m diameter telescope, a scan mechanism, a multifrequency laser system, electronics boxes, and thermal radiators.
SAAX 0245	PPS-PODS		40	
SAAX 0246	MAG	TBD	10	Sensor consists of an 8-m boom with two 2.75 m appendages mounted at right angles to the boom.
SAAX 0247	MPD	0.10 x 0.21 x 0.68	10	Composed of nadir and anti-nadir rectangular viewing assemblies, plus support electronics box.
SAAX 0248	PEM		80	

Table Eos-1. Eos INSTRUMENT PHYSICAL CHARACTERISTICS AND DESCRIPTION (CONT'D)

MISSION CODE	INSTRUMENT	DIMENSIONS (m)	MASS (kg)	DESCRIPTION
NOAA 0004	S&R	TBS	50	Search and Rescue: Broadcasts distress signals from planes and ships in real-time on an L-Band.
NOAA 0005	SEM	TBS	20	Space environment monitor of Earth's near-space radiation environment. System requires zenith and 90 degree from zenith view fields.
NOAA 0006	AMSU	A1: .3 x .7 x .6 A2: .9 x .6 x .7 B: .7 x .7 x .5	105	Three separate microwave scanning units designated A1, A2, and B. All have internal reflectors that mechanically scan crosstrack through nadir and a cold-space view.
NOAA 0010	ATSR +	1 x .7 x 1	80	A long track scanning radiometer takes cross track scans at nadir and at 23 deg ahead. Has stirling cycle cooler for focal plane.
NOAA 0014	ARGOS +	TBS	70	Data collection and location system for sensors, guages, and platforms at sea. System consists of receiver, signal, and data processors, and antenna.
NOAA 0026	GOMR	TBS	150	Global Ozone Monitor Radiometer. Consists of a Total Ozone Measuring System (TOMS) and a limb scanner.

Table Eos-1. Eos INSTRUMENT PHYSICAL CHARACTERISTICS AND DESCRIPTION (CONT'D)

MISSION CODE	INSTRUMENT	DIMENSIONS (m)	MASS (kg)	DESCRIPTION
NOAA 0029	DB	TBS	110	Real-time broadcast of NOAA meterological data. System provides formatting, multiplexing, on-board storage, and transmission.
NOAA TBD	AMRIR	1 x .6 x .4	63	Imaging radiometer replacing AVHRR and HIRS. Contains optical telescope, scanner and radiant cooler.
ESA X-4	ATLID		150	
ESA X-5	SAR-C		600	Composed of two 0.2 m by 18 m foldable antennas plus support electronics and structure. The antennas are aligned along the velocity vector direction with one looking to the left of Nadir, the other to the right of Nadir.
ESA TBD	MERIS		75	
ESA TBD	CSR		60	
Japan TBD	AMSR		320	
Japan TBD	AVNIR		200	new
Japan TBD	ITIR		290	
Japan TBD	OCTS		180	
Japan TBD	SAR-L		450	
Japan TBD	SAR-X		600	

3.0 Eos SERVICING INFORMATION

3.1 General Description of Eos Servicing

Eos servicing will be performed by the STS or servicing options based on ELV launches with robotic servicing. Launches will be from Space Launch Complex (SLC) 6 at the Western Test Range (WTR), Vandenberg AFB California. Because of the large angle between Space Station and Eos orbit planes, the Space Station can be of no assistance during Eos servicing missions.

Eos servicing missions are currently undergoing definition. For STS based servicing, since the STS cannot launch directly into the Eos orbit, either the platforms have to descend using an integral propulsion system or they must be serviced in-situ using an OMV carried to orbit by the STS. For ELV based servicing, a servicing payload will be delivered to the platform for in-situ, robotic servicing. At least two ELV options are under consideration: the platform may incorporate a "resident robot" servicing system to manipulate the servicing items, or a robotic servicer may be a part of the servicing payload itself.

This Servicing Data Book, for the purpose of estimating resource requirements, will assume the current baseline of STS based servicing for the Eos platform. For this scenario, the platform will descend to the STS orbit, the STS will rendezvous with the platform and replace instruments, subsystems, and components on both a scheduled and contingency basis. Following replacement, changeout, or upgrade of instruments and subsystems, the STS will remain in the vicinity of the platform while the Eos Operations Control Center (OCC) verifies instrument performance. When the OCC is satisfied with Eos operation, the platform will return to operational orbit.

3.2 Eos Background

Many Eos instruments are evolutions of previous smaller instruments flown in aircraft, on the STS, or as free-flyers.

TABLE Eos-2. Eos Science Instrument Heritage

MISSION CODE	INSTRUMENT	HERITAGE
SAAX 0208	MODIS-T	New instrument, derived from CZCS
SAAX 0209	HIRIS	Derived from SISEX.
SAAX 0210	AMSR	Similar to LAMR.
SAAX 0211	LASA-A	Derived from LASE and LITE
SAAX 0212	SAR	From Shuttle Imaging Radar Experiment (SIR-C).
SAAX 0213	ALT	From seasat altimeter.
SAAX 0214	SCAT	From N-ROSS scatterometer.
SAAX 0215	CR	From Shuttle MAPS instrument.
SAAX 0216	ERBI	From Shuttle ERBE.
SAAX 0219	SUSIM	UARS-SUSIM
SAAX 0230	F/P INT	From High Resoolution Doppler Imager (HRDI) on UARS.
SAAX 0232	MLS	From MLS instrument on UARS.
SAAX 0233	SUBMM	None; new instrument.
SAAX 0235	IR RAD	From LRIR instrument on NIMBUS.
SAAX 0236	LAWS	From WINDSAT and NOAA/TIROS doppler wind system studied.
SAAX 0239	MODIS-N	New instrument, derived from AVHRR
SAAX 0241	GLRS	Derived from studies and aircraft instruments.
SAAX 0245	PPS-PODS	DORIS (ESA)
SAAX 0246	MAG	Derived from DE
SAAX 0247	MPD	Derived from DE
SAAX 0248	PEM	UARS-PEM
NOAA 0004	S&R	TIROS-S&R
NOAA 0005	SEM	TIROS-SEM
NOAA 0006	AMSU	AMSU
NOAA 0010	ATSR +	ERS-1 ATSR
NOAA 0014	ARGOS +	TIROS-N DCS
NOAA 0026	GOMR	TIROS-N, LIMS, and TOMS
NOAA 0029	DB	NOAA-TIROS
NOAA TBD	AMRIR	New instrument, derived from AVHRR, HIRS
ESA X-4	ATLID	
ESA X-5	SAR-C	SIR-C, ERS-1
ESA TBD	MERIS	
ESA TBD	CSR	Scanner portion of ERBI.
(JAPAN) TBD	AMSR	New instrument.
(JAPAN) TBD	AVNIR	
(JAPAN) TBD	ITIR	
(JAPAN) TBD	OCTS	
(JAPAN) TBD	SAR-L	
(JAPAN) TBD	SAR-X	

Specific information regarding the heritage of each Eos instrument and its current definition phase is shown in Table Eos-2.

3.3 Primary Role of Space Station in Servicing Eos

Eos Polar Platforms are SS elements, but the manned base will have no direct role in Eos servicing operations.

3.4 Primary Space Station Facilities Required for Servicing Eos

Eos Polar Platforms are SS elements, but the manned base will have no direct role in Eos servicing operations.

3.5 Space Station Personnel Required for Servicing Eos

Current expectations are that Eos STS based servicing will be performed by both crew payload servicing personnel and Eos instrument or subsystem specialists, advised when necessary by Eos specialists on the ground.

3.6 Servicing Precautions for Eos

TBD.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of Eos

The current Eos servicing baseline calls for STS-based servicing with the platform using an integral (on-orbit replaceable) propulsion module for performing its own orbital transfer maneuvers. However, should in-situ servicing at the platform's operational altitude (approx. 824 km.) be required, an OMV with a Flight Telerobotic Servicer would be necessary. The OMV would be launched aboard an STS from the WTR. The STS would be inserted into a low orbit (about 260 km). The OMV with its service cargo would transfer to the platform's orbit, rendezvous, and dock to the platform. Specific servicing details are being studied, but in general, servicing would include the following: platform systems and instrument ORU changeout, science instrument

replacement, and fuel replenishment (by modular ORU changeout). After the platform and instrument performance is verified, the OMV would return to the shuttle, ending the service mission. The ELV servicing options would not require the use of an OMV.

4.0 Eos SERVICING SAFETY CONSIDERATIONS

4.1 Eos Hazardous Systems

No hazards during servicing.

4.2 Eos Servicing Safety Requirements

a. Eos Safety Requirements

- Personnel

  None identified at this time.

- Spacecraft

  Install covers on sensors and radiators.

b. Eos Appendages

Servicing may be performed with Eos instrument and platform appendages deployed. This will include solar arrays and high gain antennas on the platform, and various telescopes, antennas, and boom-mounted instruments deployed from Eos instruments. These may be retracted manually if necessary. Table Eos-3 identifies the appendages planned for each Eos instrument.

5.0 Eos SERVICING INTERFACES

5.1 Eos Crew Convenience Features

None identified.

5.2 Eos Mechanical Interfaces

None identified at this time. All instruments will be attached to the polar platforms, and will have RMS grapple fixtures or attach points for portable RMS grapple fixtures. Most

TABLE Eos-3. EOS INSTRUMENT APPENDAGES

MISSION CODE	INSTRUMENT	APPENDAGES
SAAX 0208	MODIS-T	None.
SAAX 0209	HIRIS	None.
SAAX 0210	AMSR	One 4-m diameter antenna; rotates at 30 rpm during operation.
SAAX 0211	LASA-A	None.
SAAX 0212	SAR	One rectangular antenna; 4.2 x 20.0 meter on articulating support.
SAAX 0213	ALT	One 1-m diameter antenna. (Fixed antenna - not deployable)
SAAX 0214	SCAT	Six antenna elements; each 0.13 x 0.13 x 3.68 meters.
SAAX 0215	CR	None.
SAAX 0216	ERBI	None.
SAAX 0219	SUSIM	None.
SAAX 0230	F/P INT	None.
SAAX 0232	MLS	None.
SAAX 0233	SUBMM	None.
SAAX 0235	IR RAD	None.
SAAX 0236	LAWS	None.
SAAX 0239	MODIS-N	None.
SAAX 0241	GLRS	None.
SAAX 0245	PPS-PODS	
SAAX 0246	MAG	Boom mounted.
SAAX 0247	MPD	Boom.
SAAX 0248	PEM	
NOAA 0004	S&R	None.
NOAA 0005	SEM	None.
NOAA 0006	AMSU	None.
NOAA 0010	ATSR +	None.
NOAA 0014	ARGOS +	
NOAA 0026	GOMR	None
NOAA 0029	DB	
NOAA TBD	AMRIR	None.

TABLE Eos-3. Eos INSTRUMENT APPENDAGES (CONT'D)

MISSION CODE	INSTRUMENT	APPENDAGES
ESA X-4	ATLID	
ESA X-5	SAR-C	Two antennas, each 0.2 x 0.05 x 18 meters
ESA TBD	MERIS	
ESA TBD	CSR	
(JAPAN) TBD	AMSR	
(JAPAN) TBD	AVNIR	
(JAPAN) TBD	ITIR	
(JAPAN) TBD	OCTS	
(JAPAN) TBD	SAR-L	Will have large antennas
(JAPAN) TBD	SAR-X	Will have large antennas

instruments would utilize an MMS type grapple to interface with a Modular Servicing Tool (MST) as was used for the Solar Maximum Repair Mission (SMRM).

5.3 Eos Umbilical Interfaces

a. Power

See Table 4 for Eos instrument operational power requirements. Servicing power is TBD.

b. Data

See Table 4 for Eos instrument operational data rates. Servicing rates are TBD.

c. Fluid

None identified.

5.4 Eos RF Communications Interface

RF communications for servicing mission support will nomially be through the platform RF communications system. However, the platform instrument complements include NOAA Direct Broadcast and X-Band downlink capabilities. These may be used as a backup to the TDRSS link for platform servicing support.

TABLE Eos-4. Eos OPERATIONAL POWER AND COMMUNICATIONS REQUIREMENTS

		INSTRUMENT COMMUNICATIONS INTERFACE						INSTRUMENT POWER REQUIREMENTS			
MISSION CODE	INSTRUMENT	CHD kbps	DATA kbps	DUTY CYCLE (%) DAY	DUTY CYCLE (%) NIGHT	RT	STORAGE Mbit	AVG kW	PEAK kW	HR/ DAY	STNDBY kW
SAAX 0208	MODIS-T	0.5	2100	80	0	Y		0.500	0.800	24.0	0.035
SAAX 0209	HIRIS	1.	290000	15	0	Y		0.620	0.825	3.6	0.620
SAAX 0210	AMSR	0.05	100	100	100	Y		0.30	0.30	24.0	0.060
SAAX 0211	LASA-A	2.	500	50	50	N		2.50	3.00	12.0	0.100
SAAX 0212	SAR	2.	300000	5	5	Y		2.3	11.8	6.0	0.200
SAAX 0213	ALT	0.01	13	100	100			0.20	0.20	24.0	0.015
SAAX 0214	SCAT	0.01	5	100	100			0.24	0.24	18.0	0.015
SAAX 0215	CR	0.01	1	100	100	N		0.100	0.100	24.0	0.005
SAAX 0216	ERBI	0.01	0.16	100	100	N		0.022	0.022	24.0	0.005
SAAX 0219	SUSIM		2					0.02	0.02		
SAAX 0230	F/P INT	1.	5	50	0	N		0.10	0.10	12.0	0.010
SAAX 0232	MLS	1.	10	100	100			0.50	0.50	24.0	0.040
SAAX 0233	SUBMM	1.	3	100	100			0.10	0.1	24.0	0.070
SAAX 0235	IR RAD	1.	4	100	100			0.43	0.43	24.0	0.020
SAAX 0236	LAWS	1.	1000	50	50			0.8	3.0	12.0	0.400
SAAX 0239	MODIS-N	0.05	8400	80	0			0.500	0.500	24.0	
SAAX 0241	GLRS	1.	10	30	30			0.80	0.80	12.0	0.120
SAAX 0245	PPS-PODS		1					0.03	0.03		
SAAX 0246	MAG	TBD	2	100	100			.01	.01	24.0	
SAAX 0247	MPD	TBD	1	100	100			0.010	0.010	24.0	
SAAX 0248	PEM		4					0.075	0.075		
NOAA 0004	S&R		5					.07	.07		
NOAA 0005	SEM		1					.02	.02		
NOAA 0006	AMSU		5					.20	.20		
NOAA 0010	ATSR +		215					0.08	0.08		
NOAA 0014	ARGOS +		2					0.05	0.05		
NOAA 0026	GOMR		5					0.26	0.26		
NOAA 0029	DB		N/A					0.14	0.14		
NOAA TBD	AMRIR		4000					0.05	0.05		

TABLE Eos-4. Eos OPERATIONAL POWER AND COMMUNICATIONS REQUIREMENTS (CONT'D)

MISSION CODE	INSTRUMENT	INSTRUMENT COMMUNICATIONS INTERFACE CHD kbps	DATA kbps	DUTY CYCLE (%) DAY	DUTY CYCLE (%) NIGHT	RT	STORAGE Mbit	INSTRUMENT POWER REQUIREMENTS AVG kW	PEAK kW	HR/ DAY	STNDBY kW
ESA X-4	ATLID		1000					0.8	0.8		
ESA X-5	SAR-C										
ESA TBD	MERIS		4500					0.1	0.1		
ESA TBD	CSR		8					0.1	0.1		
(JAPAN) TBD	AMSR		100					0.3	0.3		
(JAPAN) TBD	AVNIR		60000					.20	0.34		
(JAPAN) TBD	ITIR		52000					0.65	0.65		
(JAPAN) TBD	OCTS		4500					0.12	0.24		
(JAPAN) TBD	SAR-L										
(JAPAN) TBD	SAR-X										

5.5 Eos Thermal Interface

Eos thermal control may be accomplished by both active and passive means. Some Eos instruments require a clear field of view to cold space for radiators. Specific temperature ranges and energy dissipation requirements for each Eos instrument are shown in Table 5.

6.0 Eos SERVICING ENVIRONMENT

6.1 Eos Pointing/Orientation Requirements

a. Exposure to Light

None identified. Most Eos instruments view the Earth or the limb of the Earth. The STS will have to ensure that Eos instrument or platform sensors do not point at the sun.

b. Thermal Control

None identified. When Eos instruments are operational, radiators must remain unblocked to allow sufficient energy dissipation. During servicing, instruments will be on keep-alive status rather than operational, and this requirement may be less stringent.

6.2 Eos Contamination Concerns

Most Eos instruments are sensitive to contamination. Many have conventional optics which must be kept clean; some have cooled optics which are particularly sensitive to contaminants. Clean room requirements and levels have not yet been identified. Specific contamination concerns for each Eos instrument are shown in Table 6.

No Eos instrument outgassing concerns have been identified at this time. Eos instruments employing high voltage detectors and power supplies will require a gas pressure of less than 1.0E-05 torr prior to power up.

TABLE Eos-5. Eos OPERATIONAL THERMAL INTERFACE REQUIREMENTS

		TEMPERATURE LIMITS (deg C)				HEAT REJECTION (kW)				
		OPERATIONAL		STANDBY		OPERATIONAL		STANDBY		
MISSION CODE	INSTRUMENT	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	COMMENTS
SAAX 0208	MODIS-T	+10	+30	0	+40	0.70	0.70		0.035	
SAAX 0209	HIRIS	+10	+30	0	+40	0.82	0.82		0.625	Radiators require clear view to cold space.
SAAX 0210	AMSR	+10	+30	0	+40	0.35	0.35		0.060	May require radiators.
SAAX 0211	LASA-A	+10	+30	0	+40	3.0	3.0		0.100	LASA housing is radiator and requires tailored view to cold space.
SAAX 0212	SAR	+10	+30	0	+40	2.5	9.5		0.25	
SAAX 0213	ALT	+10	+30	0	+40	0.20	0.20	0.015	0.015	
SAAX 0214	SCAT	+10	+30	0	+40	0.20	0.20	0.015	0.015	
SAAX 0215	CR	+10	+30	0	+40	0.075	0.075	0.005	0.005	
SAAX 0216	ERBI	+10	+30	0	+40	0.017	0.017	0.005	0.005	
SAAX 0219	SUSIM									
SAAX 0230	F/P INT	+10	+30	0	+40	0.080	0.080		0.010	
SAAX 0232	MLS	+10	+30	0	+40	0.40	0.40		0.040	
SAAX 0233	SUBMM	+10	+30	0	+40	1.80	1.80		0.070	SS radiators require clear view to cold space.
SAAX 0235	IR RAD	+10	+30	0	+40	0.43	0.43		0.020	
SAAX 0236	LAWS	+10	+30	0	+40	4.5	4.5		0.400	DL radiators require clear view to cold space.
SAAX 0239	MODIS-N	+10	+30	0	+40					Radiant cooler or refrigerator

TABLE Eos-5. Eos OPERATIONAL THERMAL INTERFACE REQUIREMENTS (CONT'D)

		TEMPERATURE LIMITS (deg C)				HEAT REJECTION (kW)				
		OPERATIONAL		STANDBY		OPERATIONAL		STANDBY		
MISSION CODE	INSTRUMENT	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	COMMENTS
SAAX 0241	GLRS	+10	+30	0	+40	0.76	0.76		0.114	
SAAX 0245	PPS-PODS									No information avail.
SAAX 0246	MAG	+10	+30	0	+40					
SAAX 0247	MPD	+10	+30	0	+40					
SAAX 0248	PEM									
NOAA 0004	S&R									
NOAA 0005	SEM									
NOAA 0006	AMSU									
NOAA 0010	ATSR +									
NOAA 0014	ARGOS +									
NOAA 0026	GOMR									
NOAA 0029	DB									
NOAA TBD	AMRIR									
ESA X-4	ATLID									
ESA X-5	SAR-C									
ESA TBD	MERIS									
ESA TBD	CSR									
(JAPAN) TBD	AMSR									
(JAPAN) TBD	AVNIR									
(JAPAN) TBD	ITIR									
(JAPAN) TBD	OCTS									
(JAPAN) TBD	SAR-L									
(JAPAN) TBD	SAR-X									

TABLE Eos-6. Eos INSTRUMENT CONTAMINATION CONCERNS

MISSION CODE	INSTRUMENT	CONTAMINATION CONCERNS
SAAX 0208	MODIS-T	Optics: sensitive to effluents, condensates, and particulate contamination.
SAAX 0209	HIRIS	Optics: sensitive to effluents, condensates, and particulate contamination.
SAAX 0210	AMSR	None identified.
SAAX 0211	LASA-A	Optical telescope sensitive to particular contamination.
SAAX 0212	SAR	None identified.
SAAX 0213	ALT	None identified.
SAAX 0214	SCAT	None identified.
SAAX 0215	CR	None identified.
SAAX 0216	ERBI	Radiation sensors susceptible to contamination.
SAAX 0219	SUSIM	Susceptible to surface contaminants.
SAAX 0230	F/P INT	Optical telescope sensitive to particulate contamination.
SAAX 0232	MLS	None identified.
SAAX 0233	SUBMM	None identified.
SAAX 0235	IR RAD	Cooled optics: sensitive to effluents, condensates, and particulate contamination.
SAAX 0236	LAWS	Optical telescope sensitive to particulate contamination.
SAAX 0239	MODIS-N	Optics: sensitive to effluents, condensates, and particulate contamination.
SAAX 0241	GLRS	Optical telescope sensitive to particulate contamination.
SAAX 0245	PPS-PODS	
SAAX 0246	MAG	No information available.
SAAX 0247	MPD	
SAAX 0248	PEM	
NOAA 0004	S&R	
NOAA 0005	SEM	
NOAA 0006	AMSU	

TABLE Eos-6. Eos INSTRUMENT CONTAMINATION CONCERNS (CONT'D)

MISSION CODE	INSTRUMENT	CONTAMINATION CONCERNS
NOAA 0010	ATSR +	
NOAA 0014	ARGOS +	
NOAA 0026	GOMR	
NOAA 0029	DB	
NOAA TBD	AMRIR	
ESA X-4	ATLID	
ESA X-5	SAR-C	
ESA TBD	MERIS	
ESA TBD	CSR	
(JAPAN) TBD	AMSR	
(JAPAN) TBD	AVNIR	
(JAPAN) TBD	ITIR	
(JAPAN) TBD	OCTS	
(JAPAN) TBD	SAR-L	
(JAPAN) TBD	SAR-X	

6.3 Eos Radiation Concerns

- None during Eos inoperative periods (servicing and storage).
- Exposure to RF radiation TBD.

7.0 Eos SERVICING ACCOMMODATIONS

7.1 Eos Equipment Access

The Eos platforms should provide ready access for most servicing activities. The nature of an earth observing platform requires large surface areas to provide mounting space for the instruments which improves equipment access.

7.2 Eos Modularity

NPOP-1 and NPOP-2 are being designed for both modularity and commonality. The connection of an instrument, or a group of instruments, to the polar platform will be based on standardized interfaces. The interface will standardize the mechanical, electrical, optical (for fiber optic data), and thermal interfaces. A "family" of standardized interfaces will be defined to support the full range of size, mass, power, etc., required. These interfaces will be common between the NPOP-1 and NPOP-2. The commonality of these interfaces to EPOP-1 and JPOP-1 is TBD.

7.3 Automated Eos Servicing

Nominal servicing activities are planned to be accomplished using the RMS and/or Flight Telerobotic Service. EVA would only be used in contingencies.

7.4 Eos Servicing in the Space Station Pressurized Modules

Not Applicable.

8.0 Eos SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Comments	Ref. Section
ORUs (including SIs)	yes	no		9.0
Flight Support Equipment	yes	TBD		10.0
Other Equipment	TBD	TBD		10.0
Servicing Equipment Carrier(s)	yes	yes		12.0
Servicing Consumables				
Propellant(s)	yes	yes		11.0
container(s)	yes	yes		11.0
Cryogen(s)	TBD	no		11.0
container(s)	TBD	no		11.0
Liquid(s)	no	no		11.0
container(s)	no	no		11.0
Gas(es)	no	no		11.0
container(s)	no	no		11.0
Other(s)	no	no		11.0
container(s)	no	no		11.0
Servicing Consumables Carrier(s)	no	no		12.0

9.0 Eos ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of Eos ORUs

ORUs which are modular subassemblies of instruments would be serviced on a regular basis as part of a preventive maintenance program or because of limited life. Examples include mechanical coolers, laser systems, cryogens, and some optics. Also, science instruments would be replaced when replacement is preferable to repair. Table Eos-7 summarizes the Eos instrument servicing requirements.

9.2 Eos ORU Physical Characteristics

All Eos instruments are expected to be on-orbit replaceable. Single instruments, or major instrument subsystem modules, would be mounted on a standardized base providing a structural and resource interface to the platform. The modularization of smaller serviceable units would be standardized based on the size and geometry classifications. Specific ORU physical characteristics are TBD. However, ORU concepts for both large and small modules or instruments are shown in Figures Eos-3 and 4.

9.3 Eos ORU Storage Requirements

Eos has no storage requirements on the Space Station.

9.4 Other Environmental Requirements for Eos ORUs

TBD.

10.0 Eos FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 Eos Flight Support Equipment (FSE)

TBD.

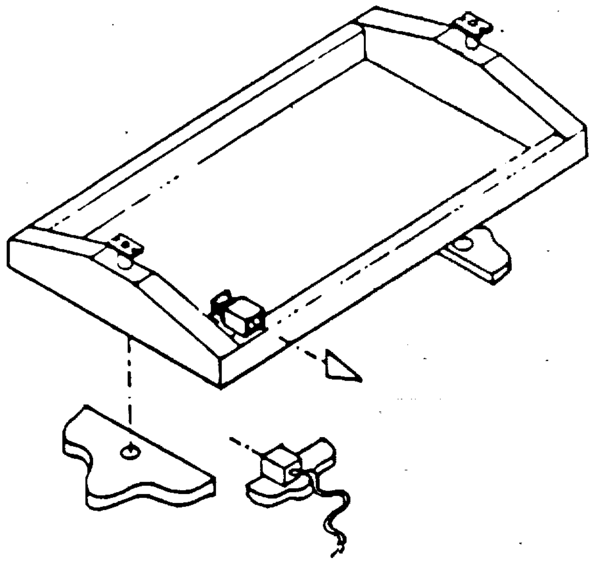
TABLE Eos-7. Eos INSTRUMENT SERVICING REQUIREMENTS

POTENTIAL INSTRUMENT ORU's

MISSION CODE	INSTRUMENT	SERVICE INTERVAL	VOLUME (M**3)	MASS (kg)	COMMENTS
SAAX 0208	MODIS-T	2 yrs	0.5	120	Electronics, Subsystems
SAAX 0209	HIRIS	4 yrs	2.0	400	Electronics, Subsystems
SAAX 0210	AMSR	2 yrs	TBD	270	Electronics, Subsystems
SAAX 0211	LASA-A	2 yrs	2.0	200	Laser Tube, Electronics, Subsystems
SAAX 0212	SAR	6 yrs	0.3	300	Electronics, Subsystems
SAAX 0213	ALT	6 yrs	0.02	30	Electronics, Subsystems
SAAX 0214	SCAT	6 yrs	0.07	50	Electronics, Subsystems
SAAX 0215	CR	6 yrs	0.5	80	Instrument
SAAX 0216	ERBI	2 yrs	0.04	30	Instrument
SAAX 0219	SUSIM	2 yrs	0.3	80	Instrument
SAAX 0230	F/P INT	6 yrs	0.05	20	Instrument
SAAX 0232	MLS	2 yrs	0.2	60	Instrument
SAAX 0233	SUBMM	2 yrs	2.0	100	Instrument
SAAX 0235	IR RAD	2 yrs	0.02	60	Instrument
SAAX 0236	LAWS	2 yrs	0.75	250	Electronics, Subsystems,
SAAX 0239	MODIS-N	4 yrs	0.5	100	Electronics, Instruments
SAAX 0241	GLRS	2 yrs	2.0	200	Laser Tube, Electronics, Subsystems
SAAX 0245	PPS-PODS				
SAAX 0246	MAG	2 yrs	TBD	TBD	Instrument
SAAX 0247	MPD				Instrument
SAAX 0248	PEM				Instrument
NOAA 0004	S&R				Instrument
NOAA 0005	SEM				Instrument
NOAA 0006	AMSU				Instrument

TABLE Eos-7. Eos INSTRUMENT SERVICING REQUIREMENTS (CONT'd)

MISSION CODE	INSTRUMENT	SERVICE INTERVAL	VOLUME (M**3)	MASS (kg)	COMMENTS
		POTENTIAL INSTRUMENT ORU's			
NOAA 0010	ATSR +				Instrument
NOAA 0014	ARGOS +				Instrument
NOAA 0026	GOMR				Instrument
NOAA 0029	DB				Electronics, Subsystems
NOAA TBD	AMRIR				Instrument
ESA X-4	ATLID				Laser, Instrument
ESA X-5	SAR-C				Electronics
ESA TBD	MERIS				Instrument
ESA TBD	CSR				Instrument
(JAPAN) TBD	AMSR				Electronics, Subsystems
(JAPAN) TBD	AVNIR				Instrument
(JAPAN) TBD	ITIR				Electronics, Subsystems
(JAPAN) TBD	OCTS				Instrument
(JAPAN) TBD	SAR-L				Electronics, Subsystems
(JAPAN) TBD	SAR-X				Electronics, Subsystems



0.75 m x 1.5 Baseplate for Instrument Mounting

Figure Eos 3. Large Orbital Replacement Unit Concept

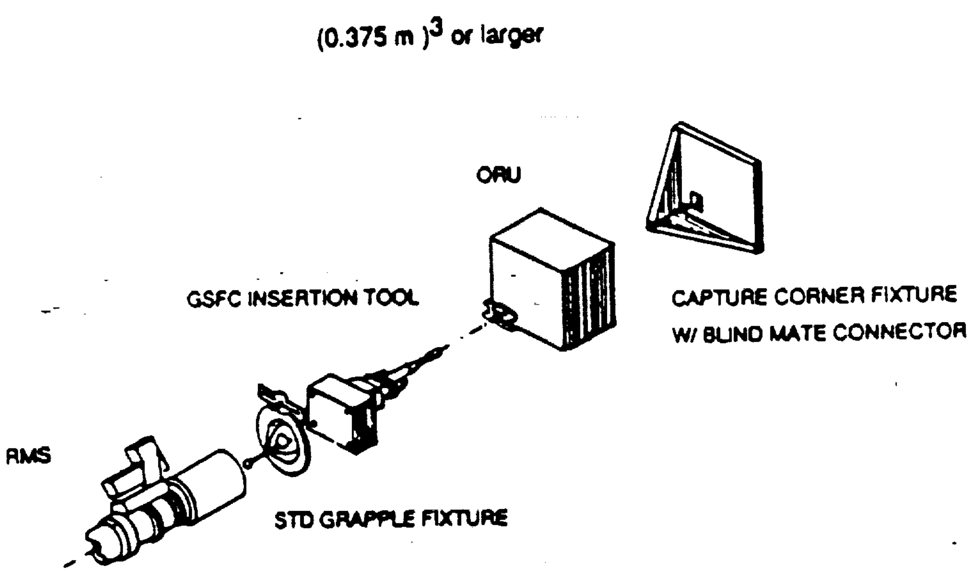


Figure Eos 4. Small Orbital Replacement Unit Module Concept

10.2 Eos FSE Physical Characteristics

TBD.

10.3 Eos FSE Storage Requirements

TBD.

10.4 Miscellaneous Servicing Equipment

TBD.

11.0 Eos SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

The only Eos consumable identified at this time is the platform's propulsion module. It is replaced on orbit with a new, fully fueled propulsion module every servicing mission.

11.2 Physical Characteristics

TBD.

11.3 Storage Requirements

TBD.

12.0 CARRIERS FOR Eos SERVICING MATERIALS

12.1 Description of Carriers

TBD.

12.2 STS and SS Carrier Interfaces

TBD.

12.3 Servicing Materials/Carrier Interfaces

TBD.

13.0 Eos ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

TBD.

13.2 Preparatory Servicing Time Estimates

TBD.

13.3 Principal Servicing Time Estimates

TBD.

13.4 Close-out Servicing Time Estimates

TBD.

14.0 Eos STRAWMAN SERVICING SCENARIO

14.1 Eos Strawman Servicing Mission

While ELV based servicing mission options provide in-situ servicing, the current mission baseline calls for Eos platforms NPOP-1 and NPOP-2 to be serviced at the STS. The servicing mission requires the platform to leave its operational orbit and descend to the shuttle's altitude. It would use its own (modular) propulsion system for the orbit transfer. A strawman servicing mission would consist of:

* preventive maintenance (ORU changeout) of Science Instruments and systems.
* preventive maintenance (ORU changeout) of platform subsystem equipment.
* science instrument replacement.
* planned unscheduled science instrument maintenance (ORU changeout).
* planned unscheduled platform subsystem maintenance (ORU changeout).
* old (depleted) propulsion module replacement with a new (fueled) propulsion module.

All servicing is nominally accomplished using the STS RMS (with MMS type end effector tool when required) to remove and replace ORU's. EVA is used only for contingency situations. All maintenance and consumables replenishment is accomplished by ORU replacement. The platform's propulsion module is exchanged with a new propulsion module every servicing mission. The old propulsion module is returned to earth for refurbishment and reuse on the next servicing mission.

The strawman servicing mission sequence would include:

- STS launched to polar orbit from WTR
- Eos platform (NPOP) descends to shuttle orbit and "rendezvous" box
- STS rendezvous with the platform
- STS RMS grapples platform and berths platform to shuttle
- Servicing operations begin

  * propulsion module replacement
  * science instrument servicing
  * platform subsystem servicing
- Science Instrument and platform systems limited checkout in shuttle bay
- RMS deberths platform from shuttle and shuttle backs away
- Platform/payload checkout while in proximity orbit with shuttle
- STS departs to safe standoff distance
- Platform boosts itself back to its operational orbit
- STS returns to launch site
- Platform performs on-orbit operational verification and returns to active status

The Eos platform operational orbit is an 824 kilometer, circular, sun-synchronous orbit with a 1:30 pm ascending nodal crossing time. The platform must descend to a servicing altitude in the 300 - 350 kilometer range. The exact altitude is chosen based on the atmospheric density for the year of the mission such that the platform would not orbit decay from that servicing altitude in less than 90 days. This provides the minimum time necessary for an STS contingency turn around at WTR to support an emergency servicing mission should the previous mission have left the platform incapable of returning to its operational altitude. In a nominal situation, the length of a servicing mission will be limited by the platform's ability to return to its operational orbit (which includes the proper nodal crossing time) and by the STS's mission duration in polar orbit.

The ELV options under study would not require the platform to leave its operational orbit. The servicing activities would not be limited by either the STS stay time nor the platform's ability to return to its operational orbit after servicing at a lower orbit.

14.2 Eos Description

The strawman servicing payload consists of two major payload units in the STS cargo bay. The first is the replacement propulsion module. The second is the ORU carrier. The ORU carrier provides the structural and resource interface for the new ORU's. Specific details are TBD.

14.3 Eos Strawman Servicing Materials

TBD.

14.4 Estimated Up/Down Mass on STS to Support Payload Strawman Servicing

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	0	0	0
ORU(s)	0	0	0
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	1900 (1)	0	1900
Equipment Carrier(s)	620 (2)	0	620
Subtotal, Equipment Mass Up	2520	0	2520
Subtotal, Equipment Mass Down	2520	0	2520
Consumables			
Consumables	3585 (3)	0	3585
Consumables Containers	695 (3)	0	695
Consumables Containers Carriers	0	0	0
Subtotal, Consumables Mass Up	4280 (4)	0	4280
Subtotal, Consumables Mass Down	875 (5)	0	875 (5)
Total Mass Up	6800	0	6800
Total Mass Down	3395	0	3395

Notes:

(1) Based on discussions with JPL and RCA. The data defines a "generic" servicing mission of 1000 kgms of Payload and 900 kgms of platform servicing materials.

(2) BDM estimate based on RCA data in "DR-02: Preliminary Analysis and Design Document, Vol 4-Platforms", December, 1986.

(3) This data represents the platform's on-orbit replaceable propulsion module.

(4) Based on RCA data in DR-02. See footnote (2).

(5) BDM estimate based on RCA data in DR-02 and includes residual fuel weight. See footnote (2).

14.5 Estimated Up/Down Volume on STS to Support Eos Strawman Servicing

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	0	0	0
ORU(s)	0	0	0
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	0	0	0
Equipment and Carriers Subtotal	0	0	0
Consumables			
Consumables in Containers	0	0	0
Consumables, Containers and Carriers	0	0	0
Total Volume Up	65^	0	65^ (1)
Total Volume Down	65^	0	65^

Notes: (1) BDM estimate based on total service mass-up. Volume down = volume up because dry propulsion module has same envelope as fueled module.

14.6 Storage on Space Station Required to Support Eos Strawman Servicing

None. Eos is a polar mission and has no direct requirements on the core station.

14.7 Eos Strawman Servicing Power Estimates

	Operational* Mode (watts)		Servicing Mode (watts)	
	AVG	MAX	AVG	MAX
Eos (Bus + Instruments)	6130	6830	1120	1620**

* Operational Values shown for reference purposes

** Peak powers greater than this may be required to support individual instrument checkout.

14.8 Eos Strawman Servicing Elapsed/IVA/EVA/MRMS Times

TBD.

14.9 OMV Flights in Support of Eos Strawman Servicing Mission

The baseline servicing mission is at the STS. The platform uses its own integral propulsion system and therefore does not require OMV support.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF Eos

15.1 Eos Milestone and Servicing Schedule

(Nominal Mission Model through 2005).

EVENT	LOCATION	DATE	COMMENT
NPOP-1 Launch	ELV at WTR	4th quarter, 1995	
NPOP-2 Launch	ELV at WTR	2nd quarter, 1997	
NPOP-1 Service	STS	4th quarter, 1998	
NPOP-2 Service	STS	2nd quarter, 2000	
NPOP-1 Service	STS	4th quarter, 2001	
NPOP-2 Service	STS	2nd quarter, 2003	
NPOP-1 Service	STS	4th quarter, 2004	

Note: EPOP-1, the European contribution to the Eos Program is planned for launch in the 1st quarter of 1997. It requires a three year service interval. Also, JPOP-1, the Japanese contribution to the Eos Program is scheduled for a launch date after that of NPOP-2, sometime in 1998. Its servicing requirements are TBD.

15.2 Summary of Eos Mass Considerations

a. Eos Mass (Operational Eos and Servicing Payload)

Oper Eos Mass (dry):	10050 kg	Servicing Payload Mass (dry):	3215 kg
Oper Consumables Mass:	2330 kg*	Servicing Consumables Mass:	3585 kg*
Oper Eos Mass (total):	12380 kg	Servicing Payload Mass(total):	6800 kg

b. Eos Servicing Mass Up and Down in STS

Event	Mass Up (kg)	Mass Down (kg)
Launch NPOP-1	12380	
Launch NPOP-2	12380	
1st Servicing	6800	3400
2nd Servicing	6800	3400
3rd Servicing	6800	3400
4th Servicing	6800	3400
5th Servicing	6800	3400
6th Servicing	6800	3400
Totals	72360	23800
Servicing Totals**	47600	23800

* Propellant weight only, propulsion module dry weight included with dry mass.

** Totals exclude initial payload launch mass, only reflect the servicing mission requirements through the year 2005, and do not include the servicing mass requirements for EPOP-1 and JPOP-1.

15.3 Summary of Eos Volume Considerations

a. Eos Volume

Eos Volume, Operational Configuration:*	TBD M^3
Eos Volume, Servicing Configuration:*	TBD M^3
Eos Volume, Storage/Transportation Configuration:*	TBD M^3

b. Eos Servicing Volumes Up and Down in STS*

Event	Volume Up M^3	Volume Down M^3
Launch NPOP-1	190	
Launch NPOP-2	190	
1st Servicing	65	65
2nd Servicing	65	65
3rd Servicing	65	65
4th Servicing	65	65
5th Servicing	65	65
Totals	705	
Servicing Totals**	325	325

* The specific instruments to be flown on NPOP-1 and NPOP-2 have not been officially selected. Consequently, the operational configuration which requires the deployed state for instruments (also solar arrays and antenna masts) is TBD at this time. Additionally, it is not known at this time whether the platform, in its servicing configuration, will be required to have all or some appendages (including solar arrays and antenna masts) either fully or partially retracted.

** Does not include initial payload launches nor does it include the requirements of EPOP-1 or JPOP-1.

15.4 Summary of Eos Power Considerations

	AVG	MAX
Eos Operational Power (Watts)	6130	6830
Eos Servicing Power (Watts)	TBD	TBD
Storage Power, Servicing Materials (Watts)	TBD	TBD

15.5 Summary of Eos Servicing Time Estimates

TBD.

15.6 Summary of OMV Flights in Support Eos Servicing

TBD.

REFERENCES

1. "Space Station Payload Engineering Requirements (PER) Document", JPL D-2549, Volume 3, Appendix II, Third Draft Initial Volume 3, Revision A, November 11, 1986.

2. "Space Station Payload Engineering Requirements (PER) Document", JPL D-2549, Volume 4, Appendix III, Revision A, November 11, 1986.

3. "Space Station Polar Platform Payload Servicing Requirements", JPL D-3177, Revision A, December 1986.

4. "Eos Baseline Deployment Scenario Changes and Platform Summary Resources", Revision 2, Eos Project Office, GSFC, June 26, 1987.

5. "Space Station Preliminary Analysis and Design Document", Data Requirement (DR)-02, Volume 2-Platforms, General Electric, December 19, 1986.

6. "Baseline Configuration Document", JSC 30255, Space Station Program Office, January 15, 1987.

7. Telephone interviews with Mr. Mike Mangano, JPL, Pasadena, California, July 1987.

8. Telephone interviews with Mr. James (Papa) Graf, JPL, Pasadena, California, August and September, 1987.

9. Telephone interviews with Mr. Marty Donahoe, NASA/GSFC, Greenbelt, Md. August, September and October, 1987.

EXPLORER PLATFORM (EP): MISSION CODE SAAX0027

1.0 EP PROGRAM AND OPERATIONS INFORMATION

1.1 EP Points of Contact

Mr. Rud Moe
NASA/GSFC
Greenbelt, MD
(301) 286-2180

Ms. Colleen Hartman
NASA/HQ
Washington, DC
(202) 453-1467

1.2 EP Objectives

Explorer missions are part of a coordinated set of astrophysics studies of the electromagnetic emissions from a wide variety of objects populating the universe. They will consist of relatively low cost missions designed to conduct investigations in astrophysics, solar physics, and plasma physics.

1.3 EP Milestone and Servicing Schedule

Launch Date: 1991 (nominally on a Delta)
First Space Station Service: 1995
Servicing Interval: 2 years
Operational Lifetime: 10 years

1.4 EP Orbital Parameters

- Free-flyer
- 540 km circular orbit at launch
- 28.5 degree inclination

2.0 EP PHYSICAL CHARACTERISTICS

2.1 EP Description

Explorers are free-flying scientific spacecraft which may be either solar, celestial, or earth pointing. Explorer missions will include missions like the Extreme Ultraviolet Explorer (EUVE) and the X-ray Timing Explorer (XTE). This report describes an Explorer-class spacecraft as a platform with a science instrument payload module attached. A typical EP platform, configured for EUVE, is shown in Figure EP-1. A payload module is connected to a Multimission Modular Spacecraft (MMS) through a Platform Equipment Deck (PED). The platform includes the following:

- Standard triangular MMS structural subsystem
- One high gain antenna
- MMS Modular Power Subsystem (MPS) module
- MMS Communciations and Data Handling (C&DH) module
- MMS Modular Attitude Control Subsystem (MACS) module.
- Platform equipment deck with solar arrays, PSU, two RIUs, interface hardware and ORU modules for future use.

The configuration for the EUVE instrument package is shown in Figure EP-2.

2.2 EP Physical Characteristics

a. Mass
  - Dry: 3035 kg (6676 lbs)
  - Wet: N/A

b. Dimensions
  - The Payload Module must be sized to fit within the proposed Delta 2.8 meter diameter fairing and the STS 2.3 meter radius thermal/dynamic envelopes defined in JSC ICD 2-19001, "Shuttle Orbital/Cargo Standard Interfaces."
  - Stowed Bus and Payload: 5 x 2.8 diameter = 31 m^3
    The two solar arrays consist of 3 panels each.

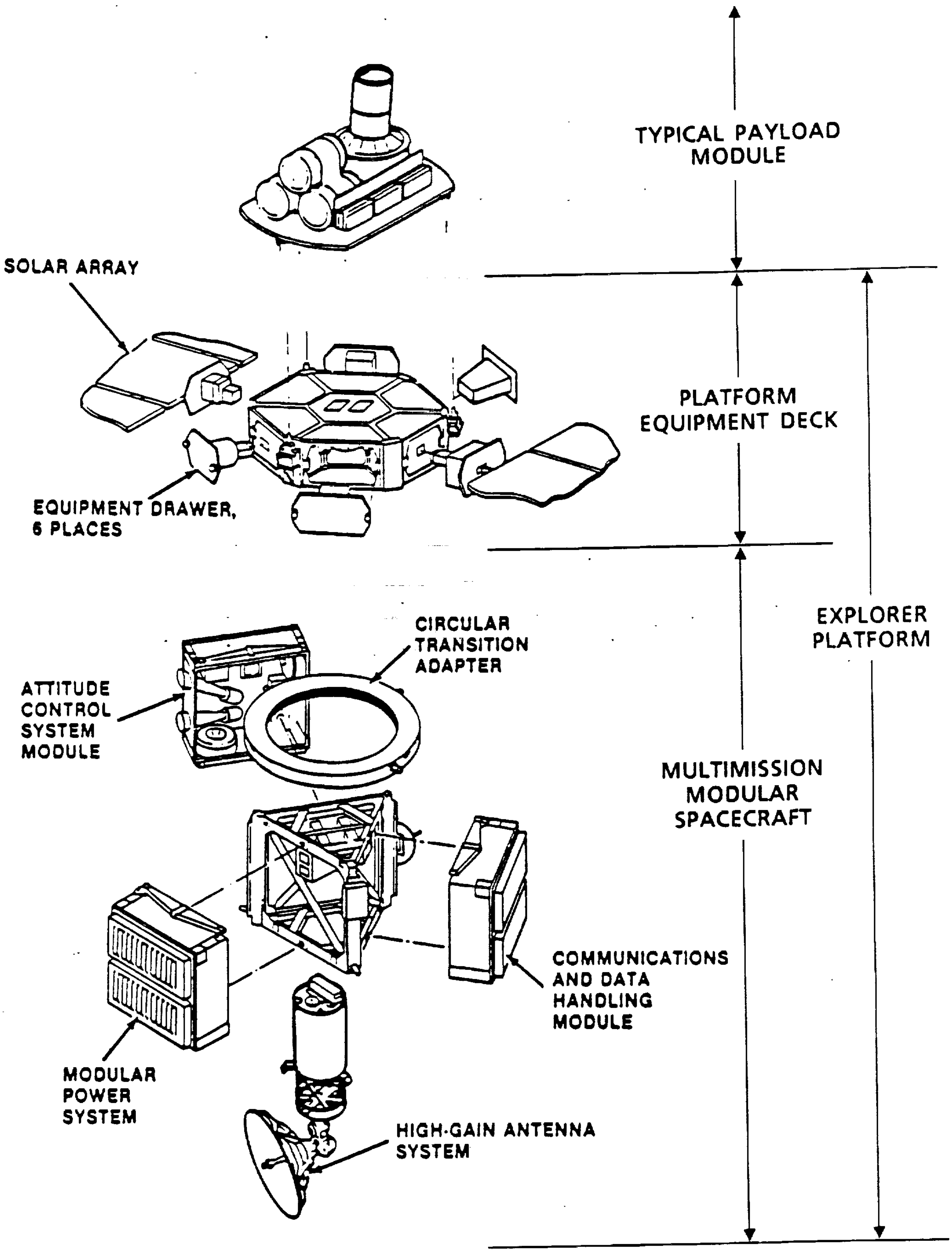


Figure 1-1. Explorer Platform Configuration

C0200*7D-05

EXTREME ULTRAVIOLET EXPLORER

SPACECRAFT INSTRUMENT CONFIGURATION

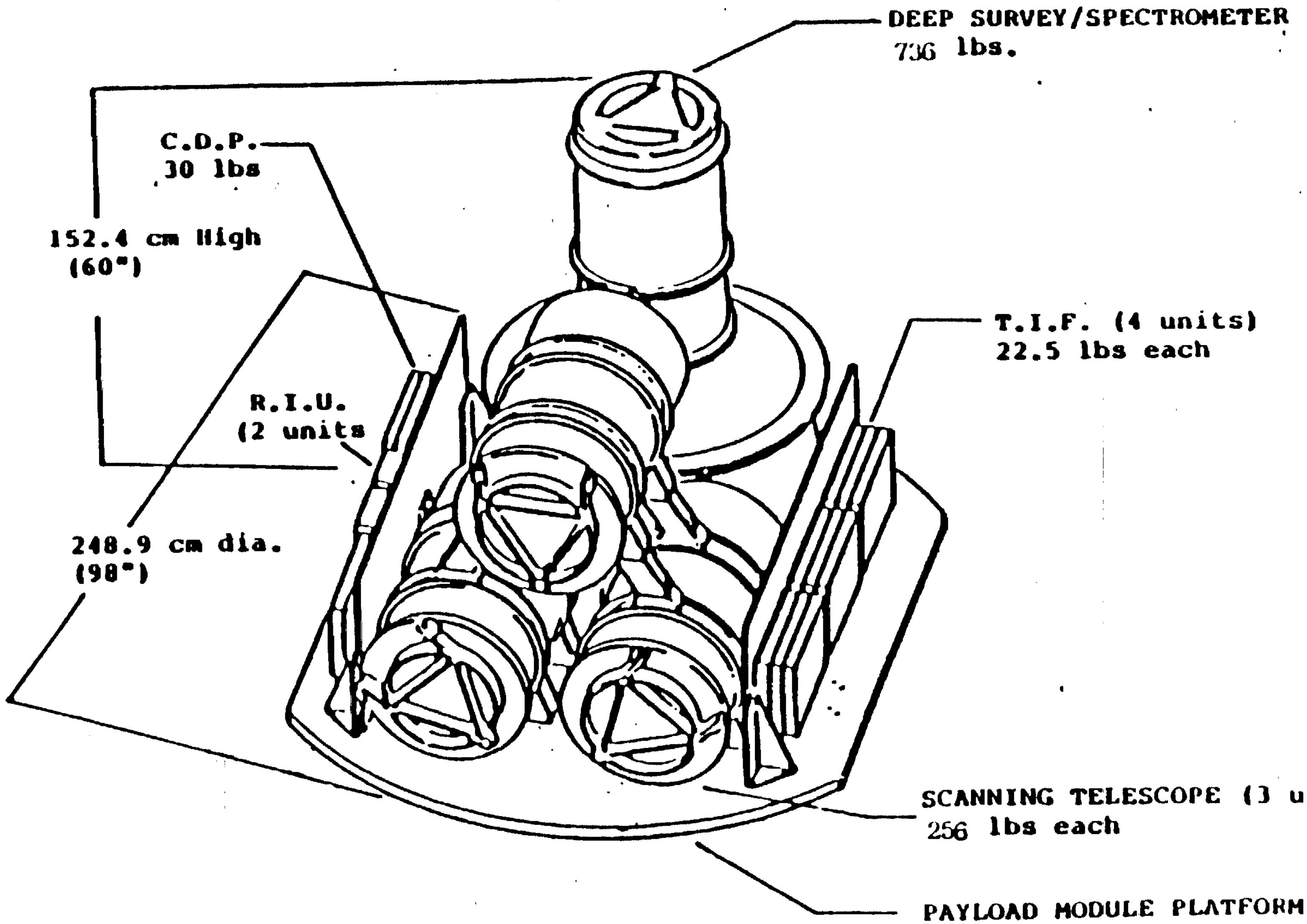


Figure EP-2. EUVE Instrument Configuration

Each panel has dimensions of 59.5 inches (151.1 cm) by 84.8 inches (215.4 cm), for an area of 3.26 m^2 per panel. Each array has 3 panels and an area of 3 (3.26) = 9.78 m^3 per array.

- Solar arrays (2): 19.5 m^2 area
- High gain antenna: 48 inch (1.2 m) dish
- High gain antenna boom: 63 inch (1.6 m) deployed length

c. Envelope

(1) Stowed: 5 x 2.8 m diameter = 31 m^3

(2) Deployed: 2.2^ x 6.2^ x 11.6^ m = 158^ m^3

2.3 EP Moving Parts and Special Features

a. Solar Arrays

EP spacecraft will typically have two solar arrays. Deployment is automatic with manual override capability. The arrays can be jettisoned or manually folded to prepare EP for earth return. Size and configuraion are EP payload dependent. The array remains deployed during servicing.

b. High Gain Antennas

Two axis gimbal is used. The antenna may be automatically retracted and caged. It is jettisonable.

2.4 EP Consumables

No consumables have been identified.

3.0 EP SERVICING INFORMATION

3.1 General Description of EP Servicing

EP will be designed for on-orbit servicing. In a typical servicing mission , EP will be retrieved by the OMV and berthed at the Space Station for 2 to 3 days. During this time, instruments will be maintained, changed out, or upgraded. Any failed or malfunctioning subsystem will be repaired or replaced. Following servicing, EP may require temporary deployment by MRMS or OMV for checkout. Following verification of satisfactory operation, the OMV will be used to return EP to its nominal operational orbit. Prior to OMV return to the Space Station, EP will be fully exercised by ground command. When the Payload Operations Control Center (POCC) is satisfied with EP operation, the OMV will return to the Space Station.

Shuttle-based servicing using FSS and RMS is also possible. This is the baseline for the first servicing mission. See Section 14.1.

3.2 EP Background

The Solar Maximum Mission (SMM) spacecraft (currently operational) is similar to some Explorer missions. The Solar Maximum Repair Mission (SMRM) in 1984 proved the efficacy of the MMS operating and servicing concept.

3.3 Primary Role of Space Station in Servicing EP

The Space Station will be used for the following:

- Changeout of science instruments at approximately 2 year intervals
- Contingency repairs.
- Contingency replacement of subsystem modules.

3.4 Primary Space Station Facilities Required for Servicing EP

Required facilities depend on the particular EP payload carried, but possibilities include a sun shield or shroud for thermal control.

3.5 Space Station Personnel Required for Servicing EP

Mission dependent. Task trainable servicing mission specialists are required. One of these specialists must be trained in FSS-equivalent and RMS operation.

3.6 Servicing Precautions for EP

Mission dependent. Install covers on sensors, radiators, and instrument apertures.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of EP

The OMV will be used to retrieve EP for science instrument replacement, and to redeploy it with a contingency return option. Two OMV round trips are thus required for each science instrument replacement.

4.0 EP SERVICING SAFETY CONSIDERATIONS

4.1 EP Hazardous Systems

Mission dependent; TBD.

4.2 EP Servicing Safety Precautions

No personnel safety precautions have been identified.

5.0 EP SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 EP Crew Convenience Features

- Modular subsystem design.
- Tether rings on outer structure.
- Corners, edges, and surfaces will be engineered for crew safety.

5.2 EP Mechanical Interfaces

- RMS grapple fixture.
- STS keel and trunnion support fitting for FSS or large EP payload module.
- FSS Berthing Latches.
- Tool interfaces on modules and FSS mechanisms.
- FSS carries locker for astronaut tools.

5.3 EP Umbilical Interfaces

a. Power

- 28 +7/-7 VDC provided by the MPS to the EP payload. The FSS provides 24 to 32 VDC to the payload module for resupply heaters, caution & warning (C & W), and launch keep-alive functions.
- 0.25 kW during servicing or storage.
- 0.3 kW average for EP payload during operation (checkout/test following servicing); 1.0 kW average total.
- Table EP-1 provides a summary of EP power demands.

b. Data

Servicing requirements are TBD.

Operational:

- 32 Kbps RT, 512 Kbps PB, or payload burst data
- FMDM-to-Orbiter Data Bus
- Various switch panel functions

c. Fluids

Mission-Dependent; TBD

5.4 EP RF Communication Interface

The EP RF communication interface requirement in support of servicing activities is TBD. Operationally, EP has the following features:

- Antennas: Two omni, one high gain antenna system (HGAS)
- Command Rates: Prime = 1 Kbps TDRSS
  Backup = 2 Kbps DSN, 125 bps TDRSS
- Telemetry Rates: 32 Kbps prime, 1 Kbps backup
- Payload Data: Up to 26 Kbps science (out of 32 Kbps total)
  Up to 512 Kbps payload direct to PMP

5.5 EP Thermal Interface

Mission dependent. Spacecraft temperatures must be maintained between -15 and +50 degrees C during servicing and storage.

TABLE EP-1: EUVE EXPLORER POWER DEMANDS SUMMARY

Item	Power (watts)
MMS/MACS	175
MMS/C&DH	175
MMS/MPS	44
MMS/Signal Conditioning & Control Unit (SC&CU)	13
MSS/High Gain Antenna System (HGAS)	18
MMS/Heaters	25
MMS Subtotal	450
PED/Power Switching Unit Remote Interface Unit (PSU/RIU)	11
PED/Heaters	15
PED Subtotal	26
EUVE/Heaters and Ion Pumps	75
EUVE/Electronics	128
EUVE Subtotal	203
MMS	450
PED	26
EUVE	203
EUVE Explorer Total	679

6.0 EP SERVICING ENVIRONMENT

6.1 EP Pointing/Orientation Constraints

a. Exposure to Light

Precautions must be observed during retrieval, deployment, and SS handling prior to covering star trackers and instrument apertures.

b. Thermal Control

EP will be oriented such that the louvered face of the MPS receives the minimum external environmental flux. Direct impingement of solar flux cannot be tolerated.

6.2 EP Contamination Concerns

Mission-dependent; TBD. For outgassing, the gas pressure must be less than 10E-05 torr prior to star tracker power-up. The EP limit is approximately 500 rads (silicon)/year for a 10 year life.

6.3 EP Radiation Concerns

None during EP inoperative periods (servicing, storage). Exposure to RF radiation is mission-dependent and TBD.

7.0 EP SERVICING ACCOMODATIONS

7.1 EP Equipment Access

All EP subsystem modules are designed for easy removal and replacement.

7.2 EP Modularity

All EP spacecraft subsystems will be modular; EP scientific instruments will be modular payloads. The communication subsystem, power subsystem and attitude control subsystem are expected to be MMS or MMS-derived modular units and will be replaced on a contingency basis.

7.3 EP Automated Servicing

Modular design, ease of access, and simple tool interfaces allow for automated servicing.

7.4 EP Servicing in the Space Station Pressurized Modules

None required

8.0 EP SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Comments	Ref. Section
ORUs (including SIs)	yes	no		9.0
Flight Support Equipment	yes	yes	FSS to be SS-supplied; tools	10.0
Other Equipment	no	no		10.0
Servicing Equipment Carrier(s)*	yes	no		12.0 12.0
Servicing Consumables**				
Propellant(s)	no	no		11.0
container(s)	no	no		11.0
Cryogen(s)	no	no		11.0
container(s)	no	no		11.0
Liquid(s)	no	no		11.0
container(s)	no	no		11.0
Gas(es)	no	no		11.0
container(s)	no	no		11.0
Other(s)	no	no		11.0
container(s)	no	no		11.0
Servicing Consumables Carrier(s)	no	no		12.0

* Carriers for servicing materials are typically used during transportation in STS orbiter and/or during storage on SS. A single carrier may be used.

** Payload dependent

9.0 EP ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of EP ORUs

a. Primary

The EP science instruments will undergo routine changeout.

b. Secondary

On an unplanned basis, the following ORUs will be replaced or repaired:

(1) Modular Power Subsystem (MPS)
(2) Modular Power Subsystem Batteries (BAT)
(3) Modular Attitude Control Subsystem (MACS)
(4) Communications and Data Handling Subsystem (C&DH)
(5) Signal Conditioning and Control Unit (SC&CU)
(6) High Gain Antenna Subsystem (HGAS)
(7) Solar Arrays (part of a PED module)
(8) Tape Recorders (part of C&DH or PED module)
(9) Power Switching Unit (PSU) (part of a PED module)

9.2 EP ORU Physical Characteristics

Major EP ORUs are science instruments (SIs). The first instrument package, EUVE, has a mass of 1470 kg (3233 lbs), a volume of 7.4 m^3, and dimensions of 1.52 m x 2.49 diameter. Table EP-2 provides mass estimates for components of EUVE Explorer. ORUs are identified in the last column of the table.

9.3 EP ORU Storage Requirements

MMS modules are 1.22 x 1.22 x 0.46 m (4 x 4 x 1.5 ft.). PED modules are 0.64 x 0.51 x 0.58 m (25 x 20 x 23 in.). Power requirements are TBD. Storage temperature for all modules is typically -5 to +45 degrees C. Storage temperature for Modular Power Subsystem (MPS) batteries is TBD.

9.4 Other Environmental Requirements for EP ORUs

No information available.

TABLE EP-2. EUVE EXPLORER MASS SUMMARY

ITEM	MASS(lbs)	MASS(kg)	ORU
MMS			
MPS	591	269	yes
ACS	475	216	yes
C&DH	342	155	yes
SC&CU	57	26	yes
STRUCTURE	200	91	
HARNESS/CONNECTORS	34	15	
GRAPPLE	20	9	
CTA	142	65	
HGAS GIMBLE/ANTENNA	120	55	
HGAS HARNESS	12	5	
TORQUER BARS (3)	115	52	
WEIGHT MARGIN	66	30	
	2174	988	
5% CONTINGENCY	109	50	
MMS SUBTOTAL	2283	1038	
PED			
PSU	20	9	yes
RIU (2)	10	5	yes
JACK SCREW MECHANISMS (3)	135	61	
COURSE SUN SENSOR	3	1	
OMNI ANTENNA (2)	4	2	
THERMAL	30	14	
HARNESS/CONNECTORS	100	45	
PRIMARY STRUCTURE	150	68	
SECONDARY STRUCTURE	180	82	
SOLAR ARRAYS	260	118	yes
MISC.	50	23	yes (batteries & recorders)
WEIGHT MARGIN	25	11	
	967	439	
20% CONTINGENCY	193	88	
PED SUBTOTAL	1160	527	
PLM (EUVE) (CONTINGENCY, WEIGHT MARGIN, AND PAP INCLUDED)	3233	1470	yes (science instruments)
MMS	2283	1038	
PED	1160	527	
PLM	3233	1470	
EUVE EXLORER SATELLITE TOTAL	6676 lbs.	3035 kg	

10.0 EP FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 EP Flight Support Equipment (FSE)

When EP is serviced at the orbiter, the U-shaped Flight Support System (FSS) maintenance platform is employed to facilitate servicing. Figure EP-3 illustrates the on-orbit servicing configuration used to replace instruments (EP payload modules). Power is provided through the FSS to EP using an umbilical. The SS must have an orbiter equivalent FSS available for servicing. Other FSE is currently being defined. FSE includes items such as sensor and radiator covers, the modular servicing tool, other standard tooling, and mission-unique cabling. Internal, pressurized storage space and IVA servicing facilities are mission dependent and TBD.

10.2 EP FSE Physical Characteristics

The FSS has mass = 1900 kg and volume $\doteq$ 17.6 m^3. This mass/volume is chargeable to EP only during the first (STS-based) servicing. For SS-based servicing, it is assumed that an FSS equivalent is available at the SS. Other FSE is TBD and assumed to be negligible in mass and volume in comparison with the science instrument.

10.3 EP FSE Storage Requirements

TBD.

10.4 Miscellaneous Servicing Equipment

No additional information available.

11.0 EP SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

EP is a free flyer which requires no consumables in its current design. Future EP payloads may require cryogens.

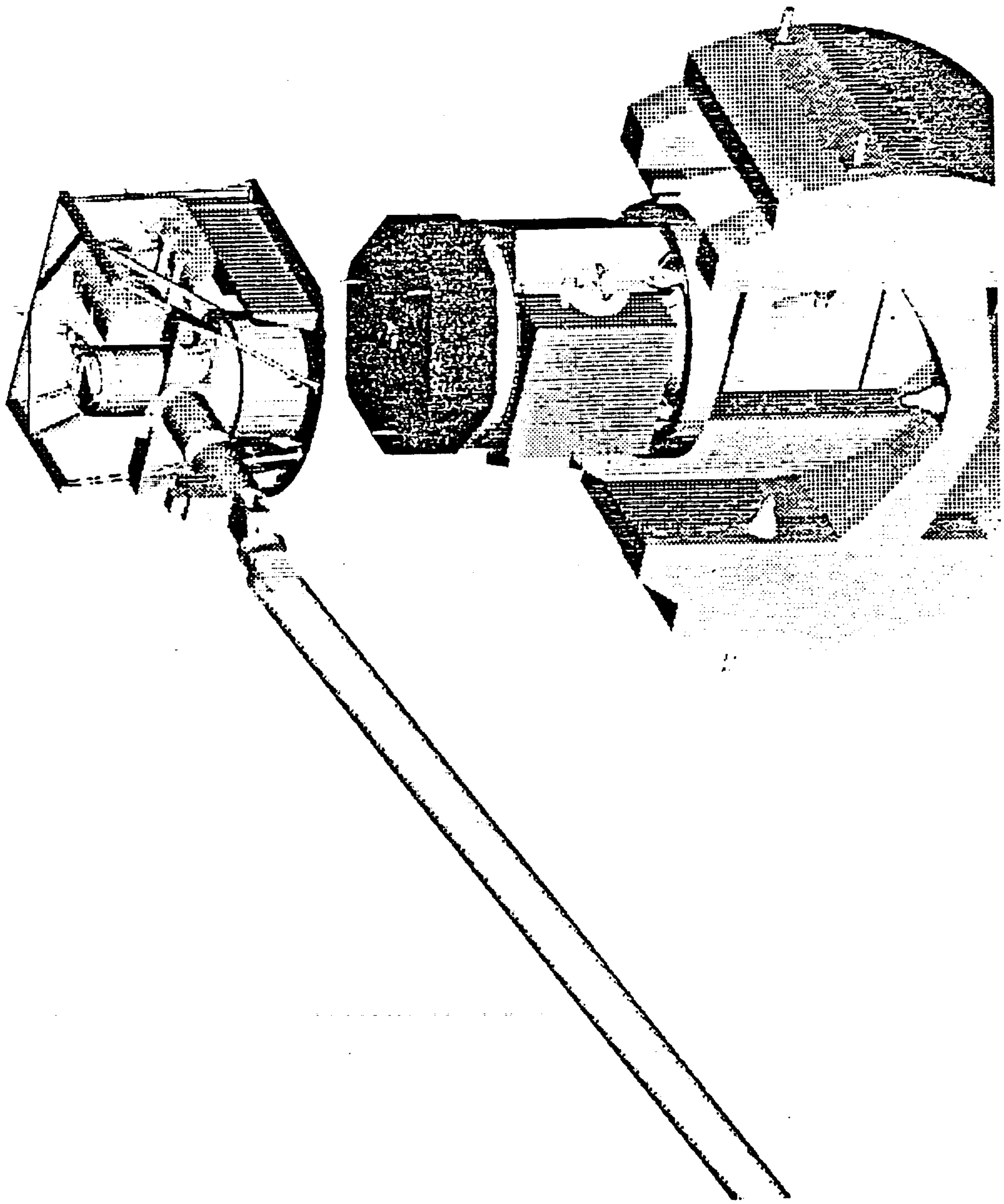


Figure EP-3. EP On-Orbit Servicing Configuration

11.2 Physical Characteristics

TBD; Mission dependent

11.3 Storage Requirements

TBD; Mission dependent

12.0 EP CARRIERS FOR EP SERVICING MATERIALS

12.1 Description of Carriers

ORU and consumables carriers are TBD.

12.2 STS and SS Carrier Interfaces

TBD.

12.3 Servicing Materials/Carrier Interfaces

TBD.

13.0 EP ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

- Explorer-class spacecraft are expected to remain at the Space Station for 2 to 3 days during each servicing mission. Less than 2 days will be devoted to payload module changeout and contingency service of modules, while checkout will take about 1 day. The OMV will be used to retrieve EP from operational orbit and return to operational orbit. Proximity operations are required before/after orbit transfers.
- The initial EP servicing mission (XTE for EUVE) will take place using the shuttle orbiter. It is assumed that by 1995 the Space Station will be able to retrieve EP using an OMV and perform subsequent servicing missions at the station.

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotic Time (hr:min)
1. Unload servicing materials from orbiter to SS	0:30^	0:30^	0:00^	0:30^
2. OMV berthing of Explorer	3:30^	3:30^	3:00^	2:00^

13.3 Principal Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotic Time (hr:min)
1. Changeout science instrument	11:05^	16:38^	0:00	5:33^

13.4 Close-out Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotic Time (hr:min)
1. OMV Deberthing of Explorer	5:30^	5:30^	3:00^	3:00^
2. Load servicing materials from SS into orbiter	0:30^	0:30^	0:00^	0:30^

14.0 EP STRAWMAN SERVICING SCENARIO

14.1 EP Strawman Servicing Mission

The Explorer strawman mission (Strawman A) is the changeout of its science instrument approximately every two years. The first changeout will occur in 1993 (after a 1991 launch) and will be performed using the STS. It will involve replacing EUVE (Figure EP-4) with XTE. Future science instruments have not been chosen yet, so it is assumed that EUVE will be representative of these payloads both in its physical characteristics and in the complexity of its changeout.

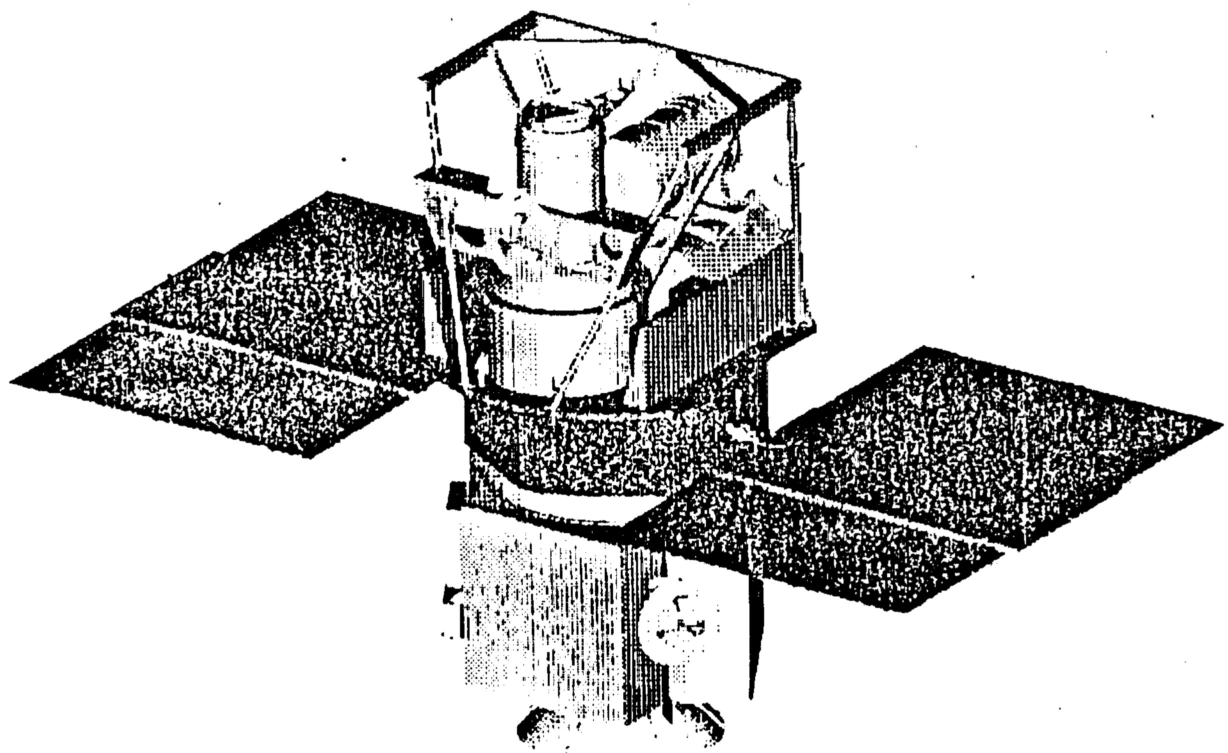


Figure EP-4. EUVE Explorer Configuration

14.2 EP Description

The EP solar arrays remain deployed during servicing.

14.3 Strawman Servicing Materials

a. ORUs

The science instrument is the only ORU for this strawman mission. Included in the changeout of this instrument is the Payload Attach Plate (PAP), with mass = 34 kg and volume estimated at 0.2^ m^3 (0.5^ x 2 m diam.). The total changeout mass is 1470 kg, with a corresponding volume of 7.6^ m^3.

Item	Number	Mass (kg)	Volume (m^3)	Power (kW)
S.I.	1	1470	7.6^	0.2

b. FSE and Miscellaneous Servicing Equipment

TBD. The payload unique flight support equipment is assumed to be negligible in mass and volume in comparison to the science instrument.

c. Consumables and Containers

TBD; mission dependent. Does not apply to EUVE Explorer or to XTE-for-EUVE changeout.

d. Carriers

Carrier information for the S.I. is TBD. The mass and volume of the carrier may be estimated using the equations described in Appendix C and summarized in Appendix D. Thus from Appendix D, Page 4, the mass of the carrier is assumed to be (.57) (1470^ kg) = 838^ kg, and the corresponding volume is (1.16) (7.6^ m^3) = 8.8^ m^2.

14.4 Estimated Up/Down Mass on STS to Support EP Strawman Servicing

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	1470	0	1470
ORU(s)	0	0	0
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	1470	0	1470
Equipment Carrier(s)	838^	0	838^
Subtotal, Equipment Mass Up	2308^	0	2308^
Subtotal, Equipment Mass Down	2308^	0	2308^
Consumables			
Consumables	0	0	0
Consumables Containers	0	0	0
Consumables Containers Carriers	0	0	0
Subtotal, Consumables Mass Up	0	0	0
Subtotal, Consumables Mass Down	0	0	0
Total Mass Up	2308^	0	2308^
Total Mass Down	2308^	0	2308^

14.5 Estimated Up/Down Volume on STS to Support EP Strawman Servicing

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	7.6^(Includes PAP)	0	7.6^(Includes PAP)
ORU(s)	0	0	0
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	7.6^	0	7.6^
Equipment Carrier	8.8^	0	8.8^
Equipment and Carrier Subtotal*	16.4^	0	16.4^
Consumables			
Consumables in Containers	0	0	0
Consumables, Containers and Carriers	0	0	0
Total Volume Up	16.4^	0	16.4^
Total Volume Down	16.4^	0	16.4^

*Equipment Volume and Equipment Carrier Volume are additive because of the assumption that the equipment is attached to the carrier rather than stowed within the carrier volume.

14.6 Storage on Space Station Required to Support Strawman EP Servicing

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	0	0	0
Volume (m^3)	0	0	0
Average Power (watts)	0	0	0
Temperature Range (^oC)	-	-	-
Temporary Storage			
Mass (kg)	2308^	0	2308^
Volume (m^3)	16.4^	0	16.4^
Average Power (watts)	250	0	250
Temperature Range (^oC)	-5 to +45	-	-5 to +45

14.7 EP Strawman Servicing Power Estimates

	Operational Mode (watts)		Servicing Mode (watts)	
	AVG	MAX	AVG	MAX
EP (Bus + Instruments)	700	TBD	250	TBD

14.8 EP Strawman Servicing Times

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotic Time (hr:min)
1. Unloading of Service Material from Orbiter to SS	0:30^	0:30^	0:00	0:30^
2. EP Berthing related activities	3:30^	3:30^	3:00^	2:00^
3. SI Changeout	11:05^	16:38^	0:00	5:33^
4. EP Deberthing related activities	5:30^	5:30^	3:00^	3:00^
5. Loading of Service Material from SS into Orbiter	0:30^	0:30^	0:00	0:30^
Totals	21:05^	26:38^	6:00^	12:33^

NOTE:
Current plans are for no EVA except as a contingency for two-fault occurrence, i.e., EVA is a backup to redundant mechanisms. Robotics can substitute for EVA on these backup functions by using similar tools.

14.9 OMV Flights in Support of EP Strawman Servicing Mission

Strawman Mission	Purpose of Flight	Number of Flights
A	Retrieval of EP	1
A	Deployment of EP	1

15.0 Overall Requirements Summary for SS Servicing of EP

15.1 EP Milestones and Servicing Schedule (Nominal Mission Model)

Event	Location	Date	Comment
Payload Launch	STS/KSC	1st quarter, 1991	
1st Servicing	STS	1st quarter, 1993	
2nd Servicing	SS	1st quarter, 1995	Strawman A
3rd Servicing	SS	1st quarter, 1997	Strawman A
4th Servicing	SS	1st quarter, 1999	Strawman A
EP Mission Termination		1st quarter, 2001	

15.2 Summary of EP Mass Considerations

a. EP Mass (Operational EP and EP During Servicing)

EP Mass (dry):	3035 kg
Consumables Mass:	0 kg
EP Mass (total):	3035 kg

b. EP Servicing Mass Up and Down in STS

Event	Mass Up (kg)	Mass Down (kg)
Launch	4935^ (includes FSS)	1900 (FSS)
1st Servicing	4208^ (includes FSS)	4208^ (includes FSS)
2nd Servicing	2308^	2308^
3rd Servicing	2308^	2308^
4th Servicing	2308^	2308^
EP Mission Termination	1900 (FSS)	4935^ (includes FSS)
Totals	17967^	17967^
Servicing Totals	11132^	11132^

c. EP Servicing Storage Mass on Space Station

Calendar Year	94	95	96	97	98	99	00	01	02	03	04	05
Storage Mass (kg)												
Unpressurized	0	2308^	0	2308^	0	2308^	0	0	0	0	0	0
Pressurized	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	2308^	0	2308^	0	2308^	0	0	0	0	0	0

15.3 Summary of EP Volume Considerations

a. EP Volume

Operational Configuration (Envelope):	158 m^3
Servicing Configuration:	158 m^3
Storage/Transportation Configuration:	31 m^3

b. EP Servicing Volumes Up and Down in STS

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	47.0^ (includes FSS)	16.0 (FSS)
1st Servicing	32.4^ (includes FSS)	32.4^ (includes FSS)
2nd Servicing	16.4^	16.4^
3rd Servicing	16.4^	16.4^
4th Servicing	16.4^	16.4^
Payload Mission Termination	16.0 (FSS)	47.0 (includes FSS)
Totals	144.6^	144.6^
Servicing Totals	81.6^	81.6^

c. EP Servicing Storage Volume on Space Station

Calendar Year	94	95	96	97	98	99	00	01	02	03	04	0
Storage Volume (m^3)												
Unpressurized	0	16.4^	0	16.4^	0	16.4^	0	0	0	0	0	0
Pressurized	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	16.4^	0	16.4^	0	16.4^	0	0	0	0	0	0

15.4 Summary of EP Power Considerations

	AVG	MAX
Operational Power (watts)	700	TBD
Servicing Power (watts)	250	TBD
Storage Power, Servicing Materials (watts)	250	TBD

15.5 Summary of EP Servicing Time Estimates

Calendar Year	94	95	96	97	98	99	00	01	02	03	04	05	TOTAL
Elapsed Time (hr:min)	0	21:05^	0	21:05^	0	21:05^	0	0	0	0	0	0	63:15^
IVA Time (Crew-hr:min)	0	26:38^	0	26:38^	0	26:38^	0	0	0	0	0	0	79:54^
EVA Time (Crew-hr:min)	0	6:00^	0	6:00^	0	6:00^	0	0	0	0	0	0	18:00^
Total Crew Time (hr:min)	0	32:28^	0	32:28^	0	32:28^	0	0	0	0	0	0	97:54^
Robotic Time (hr:min)	0	12:33^	0	12:33^	0	12:33^	0	0	0	0	0	0	37:39^

15.6 Summary of OMV Flights in Support of EP Servicing

CALENDAR YEAR	NUMBER OF FLIGHTS	PURPOSE
1994	0	
1995	2	Retrieval and deployment
1996	0	
1997	2	Retrieval and deployment
1998	0	
1999	2	Retrieval and deployment
2000	0	
2001	1	Retrieval
2002	0	
2003	0	
2004	0	
2005	0	

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1. Interview with Mr. Rud Moe, July 24 and November 2, 1987.

2. "Explorer Platform System Concept Review", July 8, 1987.

3. Explorer Platform User's Guide, July, 1987.

4. "Extreme Ultraviolet Explorer (EUVE) Mission System Concept Review", July 7-8, 1987.

5. Mission Requirements Data Base (MRDB), NASA/JSC, January 17, 1987

GAMMA RAY OBSERVATORY (GRO): MISSION CODE SAAX0013

1.0 GRO PROGRAM AND OPERATIONS INFORMATION

1.1 GRO Points of Contact

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Mr. John Hrastar
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Mr. E. Humphrey
GRO Systems Manager
NASA/GSFC
(301) 286-5897

1.2 GRO Objectives

To study gamma ray emitting objects, evolutionary forces in neutron stars and black holes, to search for evidence of nucleosynthesis, to investigate gamma rays in other galaxies, and to search for primordial black hole emissions.

1.3 GRO Milestone and Servicing Schedule

Launch Date: 1st quarter, 1990.

First Space Station Service: 1st quarter, 1994.

Servicing Interval: 4 years.

Operational Lifetime: 4 years without reboost or refueling; 8 years with reboost and refueling.

1.4 GRO Orbital Parameters

GRO is a free-flyer which will operate in a nominal altitude range of 350-450 km in a 28.5 degree inclination circular orbit. Current plans are for GRO to use its internal propulsion system to boost its altitude from its STS deployment altitude to its nominal operational altitude. The minimum STS deployment altitude for GRO is 296 km (160 N.Mi.) although a deployment in the range of 400-450 km, which would greatly conserve GRO's propellant usage, is being considered. Near the end of its first four years of operations, GRO's altitude may be allowed to decay to (no less than) 350 km in preparation for its first servicing mission.

2.0 GRO PHYSICAL CHARACTERISTICS

2.1 GRO Description

GRO is a free-flying celestial pointer. The spacecraft carries four science instruments, has an integral propulsion subsystem and uses modified NASA Multi-Mission Spacecraft (MMS) subsystems to provide power and communications. Figure GRO-1 shows the deployed GRO spacecraft.

GRO's science instruments include: the oriented scintillation spectrometer experiment (OSSE), the Compton telescope (COMPTEL), the energetic gamma ray experiment (EGRET), and the burst and transient source experiment (BATSE).

2.2 GRO Physical Characteristics

The following table summarizes GRO's overall physical structure.

a. Mass:
- Dry: 13885 kg
- Wet: 15790 kg

b. Dimensions:
- Length: 9.6 m
- Width: 21.5 m
- Height: 9.0 m
- Solar Arrays (2): 3.3^ x 5.5^m (each)
- Solar Array Booms: 3.2^m long (each)
- High Gain Antenna: 1.5^m dia
- High Gain Antenna Boom: 5^m

c. Envelope:
- Stowed: 7.7^ x 5.0^m dia
- Deployed: 9.0^ x 9.6^ x 21.5^m

2.3 GRO Moving Parts and Special Features

a. Solar Arrays
- Single gimbal, rigid fold-out arrays; deployed position shown in Figure GRO-1.
- Automatic deployment; manual retraction; EVA override for storage latches and deployment mechanism.
- Jettisonable

b. High Gain Antenna
- Two axis gimbal; deployed as shown in Figure GRO-1.
- Automatic deployment; manual retraction; EVA override for stowage latches and deployment mechanism.
- Jettisonable by cutting coaxial cable.

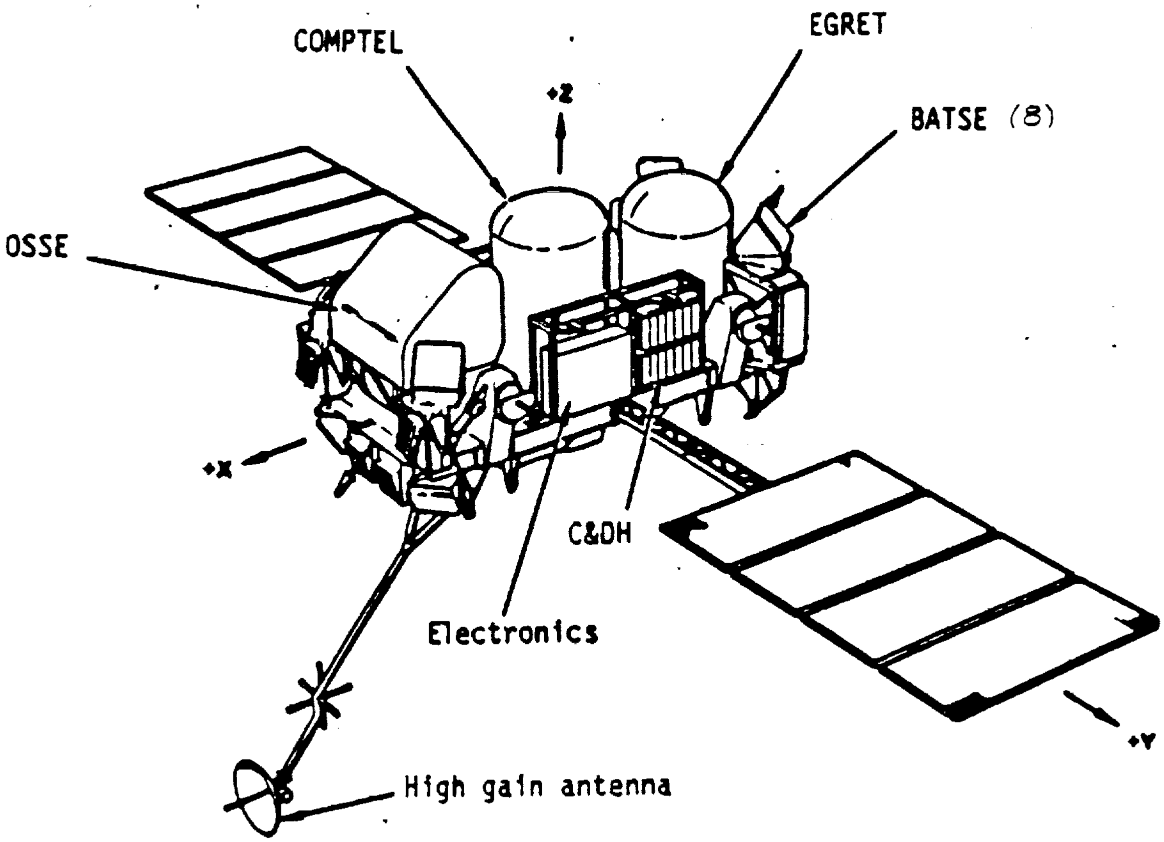

Figure GRO-1. The Gamma Ray Observatory

2.4 GRO Consumables

GRO has its own on board propulsion system with 1905 kilograms (4200 lbs) of hydrazine propellant. The current fuel allocation by function is, approximately:

- 580 kg: for initial ascent to operational altitude assuming STS release at 296 km
- 315 kg: for orbit altitude maintenance.
- 129 kg: for altitude control
- 336 kg: rendezvous ops for STS based servicing (assumming descent from 350 km to STS rendezvous at 315 km, phasing, etc.)
- 454 kg: for end of mission controlled reentry
- 91 kg: propellant reserve of 5%

The amount of consumables replenishment required by GRO will depend upon actual operational consumption rates and on the specific requirements of the servicing scenario. Nominally, the Space Station based servicing of GRO will need to replenish the fuel consumed in accomplishing the first three functions in the above list for a total of 1024 kg or hydrazine.

3.0 GRO SERVICING INFORMATION

3.1 General Description of GRO Servicing

GRO's planned servicing interval is 4 years. It's servicing options include both STS based and Space Station based servicing. In either case, the nominal servicing activities would be limited to GRO refueling and/or reboost. Contingency servicing actions would consist of limited ORU replacement operations.

The nominal scenario for Space Station based servicing is for a station based OMV to retrieve GRO from its operationa orbit and return it to the SS where it would be refueled. Refueling would be from an OSCARS or OSCARS equivalent tanker with appropriate interface. The OMV would then return GRO to its operational altitude and wait for a successful checkout of GRO before returning to the station. If for any reason GRO did not checkout properly, OMV would return GRO to the station for

contingency servicing.
GRO's options for station based servicing include either using its own propulsion system to return to the station for refueling/servicing or having a station based OMV rendezvous with and reboost GRO to lengthen its orbital life without returning GRO to the station. In the first case, an OMV flight would still be required to rendezvous with GRO and perform the terminal phase SS approach and docking maneuvers.

The amount of hydrazine required for GRO servicing is dependant upon the actual servicing option selected. For the purposes of this Data Book, the baseline servicing mission is the nominal scenario described above where the OMV is used to retrieve GRO to the station for servicing, and to then redeploy it. This is the basis of the consumables estimates of section 11.

3.2 GRO Background

GRO utilizes modified multimission modules with proven flight experience on the Solar Maximum Mission (SMM). These modules, the Modular Power System (MPS) and the Communications and Data Handling (C&DH) module, are designed for on-orbit replacement. Similar MPS modules are currently flying on Solar Max and Landsats 4 and 5, and have operated satisfactory for the last 7 years, without replacement, on Solar Max.

3.3 Primary Role of Space Station in Servicing GRO

Servicing GRO at the Space Station involves the replenishment of hydrazine.

3.4 Primary Space Station Facilities Required for Servicing GRO

The Space Station must supply facilities which support and enable the transfer of hydrazine propellant. This data book also assumes that the A' cradle (or its equivalent) is available in the SS service facility.

3.5 Space Station Personnel Required for Servicing GRO

Two EVA and one IVA astronauts are required for hydrazine propellant transfer.

3.6 Servicing Precautions for GRO

Use the SA hand-hold when manually stowing and latching SAs.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of GRO

The OMV will be utilized both for retrieval and for reboost of GRO after servicing. In a contingency situation, the OMV may be utilized to initiate a controlled reentry of GRO.

4.0 GRO SERVICING SAFETY CONSIDERATIONS

4.1 GRO Hazardous Systems

GRO's propellant system presents potential hazards to Space Station servicing personnel. Snag points where the reaction jets protrude from the spacecraft also present a hazard to personnel.

4.2 GRO Servicing Safety Precautions

Observe standard safety practices during hydrazine transfer.

5.0 GRO SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 GRO Crew Convenience Features

- Rounded corners to avoid snagging or tearing of astronaut suits.
- Handrail on last link of SA boom to aid in SA latching.
- Handholds and foot-restraint sockets.

5.2 GRO Mechanical Interfaces

GRO berths to the A' cradle or equivalent on the SS.

5.3 GRO Umbilical Interfaces

After berthing to the A' cradle, an umbilical will need to be hooked up to GRO (EVA required) to provide both power and a

hardwire for telemetry. TBD kilowatts of power at 28 vdc are required to maintain GRO systems (mainly heater power) and to support limited system checks. The hardwire supports transmission of GRO telemetry data to Space Station. GRO requires an RF link to receive commands.

5.4 GRO RF Communication Interface

GRO requires an STS or TDRSS type RF link in order to receive commands to support servicing activities. Data rates 125 bps and 1 Kbps for TDRS and 2 Kbps for STS.

5.5 GRO Thermal Interface

GRO has no interface to the Station's thermal fluid loop. GRO will be in a powered down state and will maintain its own passive thermal control.

6.0 GRO SERVICING ENVIRONMENT

6.1 GRO Pointing/Orientation Constraints

None specified.

6.2 GRO Contamination Concerns

Certain solvents including hydrofluorocarbons cause stress crazing of COMPTEL's and EGRET's anticoincidence domes.

6.3 GRO Radiation Concerns

None identified.

7.0 GRO SERVICING ACCOMMODATIONS

7.1 GRO Equipment Access

With the exception of the MMS modules and the propulsion system, GRO was not designed for ease of servicing. The MMS modules as well as the propellant fuel port are readily accessible. The science instruments are large, heavy, employ an imposing number of bolts and obstruct access to each other relative to servicing.

7.2. GRO Modularity

GRO was not designed as a modular spacecraft with the exception of the inherent modularity of the three MMS modules utilized. GRO utilizes two Modular Power System (MPS) modules and one Communications and Data Handling (C&DH) module.

7.3 GRO Automated Servicing

GRO refueling presently requires manual connection and disconnection of umbilicals. Potential does exist for future automated mating/demating of fluid and electrical disconnects.

7.4 GRO Servicing in the Space Station Pressurized Modules

No planned servicing requires the use of the SS pressurized modules.

8.0 GRO SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Ref.Section
ORUs (including SIs)	no	no	9.0
Flight Support Equipment	yes	yes	10.0
Other Equipment	no	no	10.0
Servicing Equipment Carrier(s)	no	no	12.0
Servicing Consumables			
Propellant(s)	yes	yes	11.0
container(s)	yes	yes	11.0
Cryogen(s)	no	no	11.0
container(s)	no	no	11.0
Liquids(s)	no	no	11.0
container(s)	no	no	11.0
Gas(es)	no	no	11.0
container(s)	no	no	11.0
Other(s)	no	no	11.0
container(s)	no	no	11.0
Servicing Consumables Carrier(s)	yes	yes	12.0

9.0 GRO ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of GRO ORUs

a. Primary
Primary servicing consists of hydrazine fuel replenishment and requires no ORU based servicing activities.

b. Secondary
Contingency servicing may require replacement of the (MMS) power or data system modules. Also, the EGRET instrument may need a consumables replenishment of its neon gas supply, possibly by ORU changeout, in order to extend its operational life beyond 4 years.

9.2 GRO ORU Physical Characteristics

Nominal servicing does not require ORU replacement.

9.3 GRO ORU Storage Requirements

Not Required.

9.4 Other Environmental Requirements for GRO ORUs

Not Required.

10.0 GRO FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 GRO Flight Support Equipment (FSE)

Hydrazine is assumed to be available at the SS along with the required transfer equipment. Because this equipment is assumed to be provided by the SS, it is not tabulated in this section as up/down mass to support GRO.

10.2 GRO FSE Physical Characteristics

FSE is assumed to be provided by the SS.

10.3 GRO FSE Storage Requirements

FSE is assumed to be provided by the SS.

10.4 Miscellaneous Servicing Equipment

None specified.

11.0 GRO SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

GRO has a hydrazine propulsion system. It is used for orbit transfer and rendezvous maneuvers, altitude maintenance, altitude control and for end of mission termination through controlled reentry. The propulsion system has a capacity of 1905 kg (4200 lbs) of hydrazine. It is anticipated that the first servicing mission's refueling requirement, after four years of operations, will be for 1024 kg of hydrazine to top-off the tanks.

11.2 Physical Characteristics

Consumable	Mass	Volume
Hydrazine	1024 kg	1 m^3

11.3 Storage Requirements

Hydrazine storage is assumed to be the responsibility of the SS.

12.0 CARRIERS FOR GRO SERVICING MATERIALS

12.1 Description of Carrier

No information available.

12.2 STS and SS Carrier Interfaces

STS and SS Carrier interfaces are not applicable since GRO is not responsible for establishing the SS hydrazine tank.

12.3 Servicing Materials/Carrier Interfaces

The SS is assumed to provide all servicing materials/carrier interfaces required to establish this SS hydrazine tank.

13.0 GRO ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

This document does not address contingency service missions. As no Space Station servicing operations are planned other than refueling, hydrazine replenishment is assumed to be the only servicing event required by GRO.

This document assumes that the A' cradle or its SS-equivalent is available in the service bay.

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
Berth GRO to SS	3:30^	3:30^	3:00^	2:00^

13.3 Principal Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
Replenish Hydrazine	6:00	6:00	12:00	0:00

13.4 Close-Out Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
Deberth GRO from SS	5:30^	5:30^	3:00^	3:00^

14.0 GRO STRAWMAN SERVICING SCENARIO

14.1 GRO Strawman Servicing Mission

This servicing scenario, strawman A, describes the replenishment of 1024 kg of hydrazine four years after GRO launch. The OMV retrieves GRO which then berths to the A' cradle (or its equivalent). Hydrazine is replenished. GRO deberths and is then boosted/redeployed via the OMV.

14.2 GRO Description

GRO, at SS-servicing, will have a mass of about 14800 kg and will have a stowed volume of 150^ m^3. Deployed, GRO's dimensions are 9.0^m x 9.6^m x 21.5^ m, which represent an envelope of 1860^m^3.

14.3 Strawman Servicing Materials

a. ORUs

GRO's planned servicing scenario involves no ORUs.

b. FSE and Miscellaneous Equipment

Equipment required to support GRO servicing is assumed to be provided by the SS.

c. Consumables and Containers

GRO's servicing mission will involve the replenishment of 1024 kg hydrazine of volume 1 m^3. The SS provides the storage tank.

d. Carriers

Carriers required to bring hydrazine to the SS are an SS program responsibility.

14.4 Estimated Up/Down Mass on STS to Support GRO Strawman Servicing

No servicing material is needed other than that available on the SS.

14.5 Estimated STS Up/Down Volume to Support GRO Strawman Servicing

No servicing material is needed other than that available on the SS.

14.6 SS Storage Required to Support Strawman GRO Servicing

All servicing material is provided by Space Station, therefore no storage space is charged to GRO.

14.7 GRO Strawman Servicing Power Estimates

	Operational Mode (W)		Servicing Mode (W)	
	AVG	MAX	AVG	MAX
GRO (Bus & Instruments)	1658	2028	TBD	2800*

* Servicing mode max power includes GRO's servicing support heaters.

14.8 GRO Strawman Servicing Time Estimates

SERVICING ACTIVITY	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Berth	3:30^	3:30^	3:00^	2:00^
2. Refuel	6:00	6:00	12:00	0:00
3. Deberth	5:30^	5:30^	3:00^	3:00^
TOTALS	15:00^	15:00^	18:00^	5:00^

14.9 OMV Flights in Support of GRO Strawman Servicing Mission

Strawman Mission	Purpose of Flight	Number of Flights
Strawman A	Retrieval	1
Strawman A	Deployment/Reboost	1

15.0 OVERALL REQUIREMENTS FOR SS SERVICING OF GRO

15.1 GRO Milestone and Servicing Schedule (Nominal Mission Model)

Event	Location	Date	Comment
GRO Launch	KSC	1st quarter, 1990	
1st Servicing	SS	1st quarter, 1994	Refueling
Payload Mission Termination	In-situ	1st quarter, 1998	

15.2 Summary of GRO Mass Considerations

a. GRO Mass (Operational GRO and GRO During Servicing)

Operational GRO Mass (dry):	13885 kg	Servicing GRO Mass (dry):	14776 kg
Operational Consumables Mass:	1905 kg	Servicing Consumables Mass:	1024 kg
Operational GRO Total:	15790 kg	Servicing GRO Mass (total):	15790 kg

b. GRO Servicing Mass Up and Down in STS

Event	Mass Up (kg)	Mass Down (kg)
Launch	15790	0
1st Servicing	0	0
Payload Mission Termination	0	0
Totals	15790	0
Servicing Total	0	0

c. GRO Servicing Storage Mass on Space Station
No storage mass is charged to GRO.

15.3 Summary of GRO Volume Considerations

a. GRO Volume

GRO Volume, Operational Configuration: 1850^ m^3
GRO Volume, Servicing Configuration: 150^ m^3
GRO Volume, Storage/Transportation Configuration: 150^ m^3

b. GRO Servicing Volumes Up and Down in STS

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	150^	0
1st Servicing	0	0
Payload Termination	0	0
Total	150^	0
Servicing Total	0	0

c. GRO Servicing Storage Volume on Space Station

No storage volume is charged to GRO.

15.4 Summary of GRO Power Considerations

	AVG	MAX
GRO Operational Power (watts)	1658	2028
GRO Servicing Power (watts)	TBD	2800
Storage Power, Servicing Materials (watts)	N.A.	N.A.

15.5 Summary of GRO Servicing Times

Calendar Year	90	91	92	93	94	95	96	97	98
Elapsed Time (Hours)	0:00	0:00	0:00	0:00	15:00^	0:00	0:00	0:00	0:00
IVA Time (Crew-hours)	0:00	0:00	0:00	0:00	15:00^	0:00	0:00	0:00	0:00
EVA Time (Crew-hours)	0:00	0:00	0:00	0:00	18:00^	0:00	0:00	0:00	0:00
Total Crew Time (Crew-hours)	0:00	0:00	0:00	0:00	48:00^	0:00	0:00	0:00	0:00
MRMS Time (Hours)	0:00	0:00	0:00	0:00	5:00^	0:00	0:00	0:00	0:00

15.6 Summary of OMV Flights in Support of GRO Servicing

Calendar Year	90	91	92	93	94	95	96	97	98
Number of OMV Flights	0	0	0	0	2	0	0	0	0

Note: Flights occur in the 1st quarter of '94. One OMV flight is for retrieval to SS, the second is to redeploy and reboost GRO back to its operational orbit.

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3. Interview with Jeremiah Madden, Project Manager, Gamma Ray Observatory (GRO), December 10, 1986.
4. Interview with Gene Humphrey, System Manager, Gamma Ray Observatory (GRO), February, 17, 1987.
5. Interview with John Hrastar, Deputy Project Manager Gamma Ray Observatory (GRO), June 4, 1987.
6. Interview with Charles E. Campbell, GSFC, June 12, 1987.
7. Interview with Kenneth Rosette, GSFC, June 12, 1987.
8. Mission Requirements Database, January, 1987, NASA/JSC.
9. Discussions with Gene Humphery, System Manager, Gamma Ray Observatory (GRO), September 28-29, 1987.

HITCHHIKER (HH): MISSION CODES SAAX 0030, 0032, 0032 WITH EARTH RADIATION BUDGET EXPERIMENT (ERBE): MISSION CODE SAAX 0250

1.0 HH/ERBE PROGRAM AND OPERATIONS INFORMATION

1.1 HH Points of Contact

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1.2 HH/ERBE Objectives

Hitchhiker objectives are to allow small science and engineering investigative payloads to take advantage of limited space and power requirements, particular timing, or specific events. The SS-based ERBE will investigate the radiative output of the tropics as a function of time of day. The benefit of flying ERBE

on the SS is the opportunity to conduct nonroutine instrument calibration.

1.3 HH/ERBE Servicing Schedule

Launch Date: First quarter, 1995
First Space Station Service: Not required
Servicing Interval: Not applicable.
Operational Lifetime: 5 years per ERBE instrument; 10 years for the experiment. Indefinite HH lifetime.

1.4 HH/ERBE Orbital Parameters

ERBE is a Space Station attached experiment; orbital parameters are those of the SS.

2.0 HH/ERBE PHYSICAL CHARACTERISTICS

2.1 HH/ERBE Description

The SS-based ERBE will consist of two Earth-viewing scanners: one for cross-track operation and the other for off-axis. Each ERBE scanner will operate for appproximately 5 years at which time it will be entirely replaced with new instrument packages. This is considered to be an operational replacement of instruments and not as a servicing function. The ERBE Scanner Instrument Package is shown in Figure HH/ERBE-1.

The ERBE scanner package includes three Earth-viewing radiometric channels, internal calibration sources and a solar-attenuator plate. One channel absorbs all wavelengths. The other two utilize filters to selectively receive either shortwave or longwave radiation. The thermister bolometer detectors, located at the focal point of the Cassegrain telescope, use space on every scan as a reference point to minimize the effect of detector drift. Two aluminum-coated mirrors (with enhanced ultraviolet reflectivity overcoating) make up this telescope. In addition to its ability to view space, the scanner may also view the sun for calibration by rotating the instrument head so that

the sun may be observed in reflection off the Mirror Attenuator Mosaic (MAM), a solar-attenuator plate.

ERBE is a SS-attached payload which may (or may not) utilize HH facilities for attachment to the SS. An advantage to using the HH facilities would be the opportunity to utilize the HH standard interfaces for attachment/detachment to the SS. The HH program also offers solutions to the interfaces/carriers required to transport the experiment to/from the SS.

SS-based HH offers a standard family of mechanical interfaces in order to accommodate various experiments. An across bay-carrier provides the frame to which mounting plates or HH-G cans will be attached. Up to 6 mounting plates or 12 HH-G cans (or a combination of both) can be supported. See Figure HH/ERBE-2. An orientation mechanism which would interface between the carrier and the SS is currently under study.

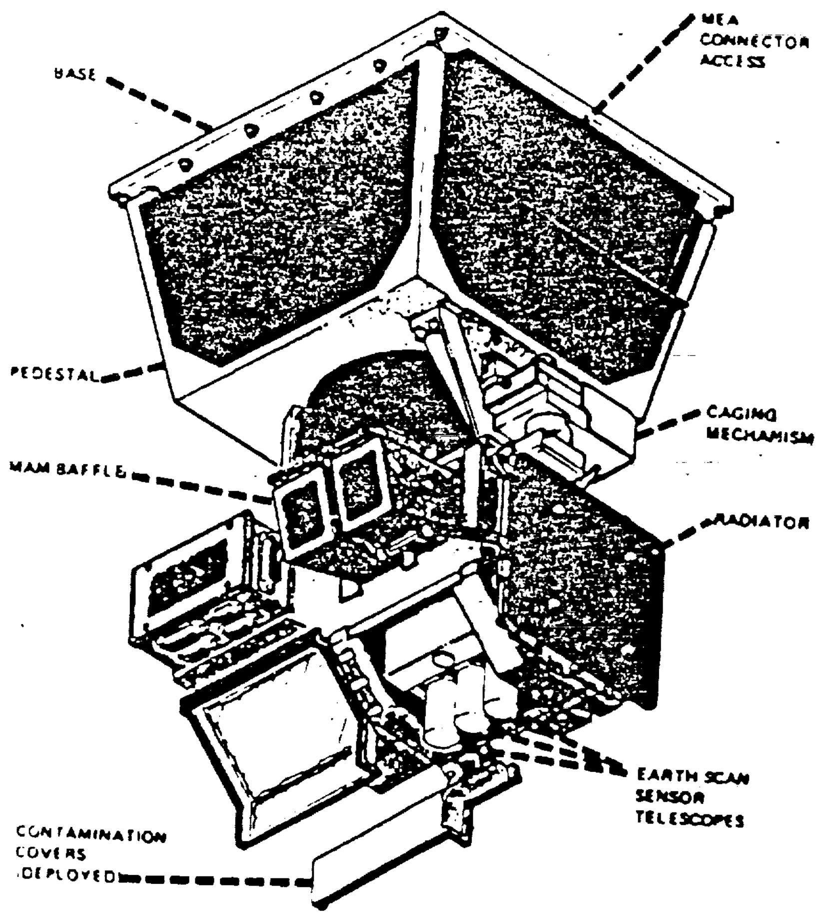

Figure HH/ERBE-1. ERBE Scanner Instrument Package

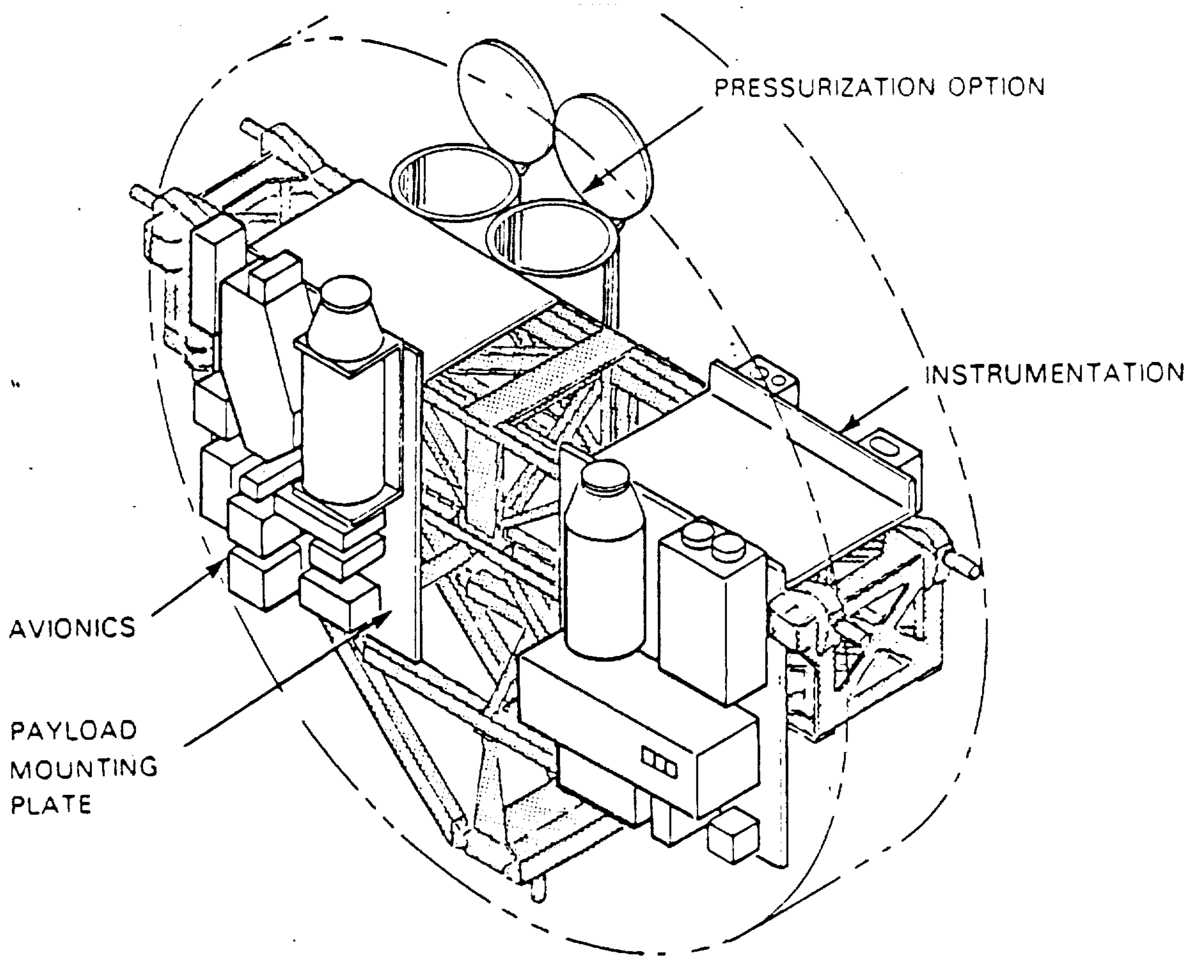

Figure HH/ERBE-2. Across Bay Carrier Mounted HH Configuration

2.2 HH/ERBE Physical Characteristics

a. ERBE

Scanner	Mass	:	40 kg
	Length	:	0.5 m
	Width	:	0.46 m
	Height	:	0.65 m
	Envelope	:	0.15 m^3
	Operational Power	:	35 W, TBD VDC

b. HH

Across Bay Carrier	Mass	:	850 kg
	Length	:	4.0 m
	Width	:	1.1 m
	Height	:	2.0 m
	Envelope	:	8.8 m^3
HH-G Can	Mass	:	90 kg
(fully insulated	Length	:	0.86 m
with motorized	Diameter	:	0.57 m
lid)	Envelope	:	0.49 m^3
Payload Mounting	Mass	:	170 kg
Plate			(240 kg with Avionics)
	Length	:	1.27 m
	Width	:	0.16 m
			(0.42 with Avionics)
	Height	:	1.52 m
	Envelope	:	0.31 m^3
			(0.81 m^3 with Avionics)

2.3 HH/ERBE Moving Parts and Special Features

ERBE scanners include two systems which move: a box beam assembly within the scan head and the azimuth rotation system. The box beam is composed of an optical telescope, radiation detectors, and electronics. The system scans back and forth to

view from one side of the Earth to the other. The scan head is mounted on the azimuth rotation system. This gimbal system rotates the scan head periodically for solar calibration. HH, itself, does not contain moving parts at this time except for the (optional) motorized HH-G can lid.

2.4 HH/ERBE Consumables

A future alternative ERBE could require cryogen replacement every 90 days. At present, however, neither ERBE nor HH requires replenishment of consumables.

3.0 HH/ERBE SERVICING INFORMATION

3.1 General Description of HH/ERBE Servicing

Neither ERBE nor Hitchhiker requires planned SS-based servicing. However, SS-based servicing may be required for ERBE in a contingency mode to replace malfunctioning subsystem modules.

3.2 HH/ERBE Background

HH/ERBE is a flight-proven experiment. Basically the same set of instruments which will be used on the SS have flown 3 times before.

3.3 Primary Role of SS in Servicing HH/ERBE

No servicing required.

3.4 Primary SS Facilities Required for Servicing HH/ERBE

No servicing required.

3.5 Space Station Personnel Required for Servicing HH/ERBE

No servicing required.

3.6 Servicing Precautions for HH/ERBE

If ERBE were to require contingency servicing then ERBE should be warmer than its environment to inhibit condensation.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Support of HH/ERBE

HH/ERBE requires no OMV support.

4.0 HH/ERBE SERVICING SAFETY CONSIDERATIONS

4.1 HH/ERBE Hazardous Systems

None.

4.2 HH/ERBE Servicing Safety Precautions

None.

5.0 HH/ERBE SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 HH/ERBE Crew Convenience Features

None specified.

5.2 HH/ERBE Mechanical Interfaces

The interface between ERBE and HH is not yet designed. An interface between ERBE and the SS (if ERBE does not use HH facilities) is also TBD.

HH-G cans and payload mounting plate attach to the across bay carrier with mechanical fasteners which can be detached via EV activity on the SS. The attachment of the carrier to the SS is TBD. The carrier uses standard active trunnion and keel fittings.

5.3 HH/ERBE Umbilical Interfaces

HH provides power via two 28 V 10 A lines. The avionics unit, if used, distributes power among up to 16 customer payloads by utilizing a microprocessor control unit, relay switching equipment, a medium-rate multiplexer, and other hardware.

The operational ERBE experiment requires a TBD DC voltage and 70 watts (2 scanners times 35 watts each) Servicing power is TBD.

5.4 HH/ERBE RF Communication Interface

RF communications for HH/ERBE Servicing are TBD. Operationally, ERBE will utilize SS facilities to transmit an estimated 8000 bps data rate (4000 bps per scanner) and an asynchronous 1200 baud uplink command channel.

5.5 HH/ERBE Thermal Interface

ERBE will not use the SS thermal fluid cooling loop. ERBE employs passive/active thermal control.

HH's Thermal Concept is characterized by:

- heater-thermostat type thermal control system.
- use of active thermal control system elements such as louvers or butterfly mechanisms will probably be required to reduce need for heater power and consequent energy requirement.
- as a goal no connection to the SS thermal system to reduce complexity of on-orbit interfacing and testing.
- self-contained fluid system (Q-tran) will be studied to supplement heater thermostat system

6.0 HH/ERBE SERVICING ENVIRONMENT

6.1 HH/ERBE Pointing/Orientation Constraints

ERBE requires a lower boom location in order to point toward the Earth. HH can be attached either to the upper or the lower boom.

6.2 HH/ERBE Contamination Concerns

ERBE is damaged by accumulative water vapor adsorption. Particulate matter, atomic oxygen, and corrosive fluids/vapors are also a concern. In addition, any substance which attenuates radiation through the shortwave and longwave filters or which decreases the reflectivity of the mirrors causes false readings, thus rendering ERBE objectives unobtainable.

6.3 HH/ERBE Radiation Concerns

Excessive exposure to UV changes ERBE reflector absorptivity, which, thus, changes the ERBE instrument's calibration.

The HH program specifies no radiation concerns.

7.0 HH/ERBE SERVICING ACCOMMODATIONS

7.1 HH/ERBE Equipment Access

The SS-based ERBE will be designed to promote ease of access to the two systems which may require replacement on a contingency basis. the attachment mechanism mounting ERBE to HH or directly to the SS should be designed to maintain this equipment accessibility.

HH has been designed to maximize ease of exchange of HH-based experiments.

7.2 HH/ERBE Modularity

The SS-based ERBE will be designed so that the electronics and the scan head modules are modular and easily replaced on a contingency basis.

HH is inherently modularly designed so that the HH progam can offer standard parts, which will accommodate various payloads.

7.3 HH/ERBE Automated Servicing

At present, HH/ERBE automated servicing is not feasible.

7.4 HH/ERBE Servicing in the Space Station Pressurized Modules

Neither HH nor ERBE require pressurized servicing.

8.0 HH/ERBE SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Ref. Section
ORUs (including SIs)	No	No	9.0
Flight Support Equipment	No	No	10.0
Other Equipment	No	No	0.0
Servicing Equipment Carrier(s)	No	No	12.0

Servicing Consumables			
Propellant(s)	No	No	11.0
container(s)	No	No	11.0
Cryogen(s)	No	No	11.0
container(s)	No	No	11.0
Liquid(s)	No	No	11.0
container(s)	No	No	11.0
Gas(es)	No	No	11.0
container(s)	No	No	11.0
Other(s)	No	No	11.0
container(s)	No	No	11.0
Servicing Consumables Carrier(s)	No	No	12.0

9.0 HH/ERBE ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of HH/ERBE ORUs

ERBE requires no SS-based servicing ORU replacement. ERBE, however, will be designed with two modular systems which could be replaced on a contingency basis. These ORUs are the electronics module and the scan head.

No HH components are identified as needing servicing.

9.2 HH/ERBE ORU Physical Characteristics

ERBE electronics module:	Mass	:	10^kg
	Length	:	TBD
	Width	:	TBD
	Height	:	TBD
	Envelope	:	0.04 ^m^3
ERBE scan head module:	Mass	:	15^kg
	Length	:	TBD
	Width	:	TBD
	Height	:	TBD
	Envelope	:	0.05 ^m^3

9.3 HH/ERBE ORU Storage Requirements

None specified.

9.4 Other Environmental Requirements for HH/ERBE ORUs

None specified. The electronics module is not ESD sensitive.

10.0 HH/ERBE FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 Payload Flight Support Equipment (FSE)

No servicing is required.

10.2 Payload FSE Physical Characteristics

Not applicable.

10.3 Payload FSE Storage Requirements

Not applicable.

10.4 Miscellaneous Servicing Equipment

None.

11.0 HH/ERBE SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

HH/ERBE requires no consumables.

11.2 Physical Characteristics

Not applicable.

11.3 Storage Requirements

Not applicable.

12.0 CARRIERS FOR HH/ERBE SERVICING MATERIALS

12.1 Description of Carriers

HH cans and mounting plates can be carried on the Orbiter by using a Gas Beam Adapter (80 kg, 0.2 m^3) rather than carrying the across bay carrier to and from the SS every time. The replacement of the entire HH/ERBE experiment every 5 years is considered to be operational, however.

12.2 STS and SS Carrier Interfaces

TBD.

12.3 Servicing Materials/Carrier Interfaces

No servicing is required.

13.0 HH/ERBE ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

No servicing is required.

13.2 Preparatory Servicing Time Estimates

No servicing is required.

13.3 Principal Servicing Time Estimates

No servicing is required.

13.4 Close-out Servicing Time Estimates

No servicing is required.

14.0 HH/ERBE STRAWMAN SERVICING SCENARIO

14.1 HH/ERBE Strawman Servicing Mission

Neither HH nor ERBE plans to require SS-based servicing.

14.2 HH/ERBE Description

HH/ERBE is described in Section 2.1.

14.3 Strawman Servicing Materials

No servicing is required.

14.4 Estimated Up/Down Mass on STS to Support Payload Strawman Servicing

Neither HH nor ERBE requires SS-based servicing.

14.5 Estimated Up/Down STS Volume to Support HH/ERBE Strawman Servicing

Neither HH nor ERBE requires SS-based servicing.

14.6 Storage on Space Station Required to Support Strawman Payload Servicing

None required.

14.7 HH/ERBE Strawman Servicing Power Estimate

	Operational Mode (W)		Servicing Mode (W)	
	Avg	Max	Avg	Max
HH/ERBE	70	TBD	N.A.	N.A.

14.8 HH/ERBE Strawman Servicing Times

No servicing is required.

14.9 OMV Flights in Support of HH/ERBE Strawman Servicing

HH/ERBE requires no OMV support.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF HH/ERBE

15.1 HH/ERBE Milestones and Servicing Schedule

Event	Location	Date
Launch 1st ERBE set	KSC	First quarter, 1995
Terminate 1st ERBE		First quarter, 2000
Launch 2nd ERBE	KSC	First quarter, 2000
Terminate 2nd ERBE		First quarter, 2005

15.2 Summary of HH/ERBE Mass Considerations

a. HH/ERBE Mass
Operational Mass: 1080 kg

b. HH/ERBE Mass Up and Down in STS

Event	Mass Up (kg)	Mass Down (kg)
Launch	1080	0
Replace HH/ERBE	390	390
Final Termination **	0	230
Total	1940^	1090^
Servicing Total	0	0

* Assumes that each scanner is mounted in a HH-G can.
** Leaves Across Bay Carrier on the SS for other HH payloads

c. HH/ERBE Servicing Storage Mass on SS

None required.

15.3 Summary of HH/ERBE Volume Considerations*

a. HH/ERBE Volume

HH/ERBE Operational Volume: 10 m^3

b. HH/ERBE Servicing Volume Up and Down in STS

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	10	0
Replace HH/ERBE	1.4	1.4
Replace HH/ERBE	1.4	1.4
Total	13 m^3	4.3 m^3
Servicing Total	0 m^3	0 m^3

* Assumes that each ERBE scanner is mounted in a HH-G can.

c. HH/ERBE Servicing Storage Volume on SS

None required.

15.4 Summary of HH/ERBE Power Considerations

	Average	Maximum
HH/ERBE Operational Power (watts)	70	TBD
HH/ERBE Servicing Power (watts)	N.A.	N.A.
Storage Power, Servicing Materials (watts)	N.A.	N.A.

15.5 Summary of HH/ERBE Servicing Time Estimates

No servicing is required.

15.6 Summary of OMV Flights in Support of HH/ERBE SS Servicing

None required.

REFERENCES

1. "The Earth Radiation Budget Experiment (ERBE)", Dr. B.R. Barkstrom, Bulletin of the American Meteorological Society, Volume 65, Number 11, November 1984.

2. Telephone conversation with Mr. John (Jack) Cooper, September 24, 1987.

3. Telephone conversations with Dr. Bruce Barkstrom, March 4, and September 1, 1987

4. Telephone conversation with Mr. Bob Keynton, NASA/LRC, August 20, 1987.

5. Conversations with Mr. Richard Day, NASA/GSFC, February 19, and August 6, 1987.

6. Presentation slides "A Concept for Space Station Hitchhiker", Mr. Ted Goldsmith, NASA/GSFC, March 22, 1985, and September 30, 1986.

7. Brochure "Hitchhiker-G and Shuttle Payload of Opportunity (SPOC) Capabilities", GSFC Document #730-1501-03.

8. Hitchhiker-G Customer Accommodations and Requirements Specification, NASA/GSFC, Document #HHG-730-1503-03, Reissued December, 1986.

9. Mission Requirements Database, January, 1987, NASA/JSC.

10. Telephone conversation with Mr. Jack Cooper, September 30, 1987.

1.0 HRSO PROGRAM AND OPERATIONS INFORMATION

1.1 HRSO Points of Contact

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1.2 HRSO Objectives

HRSO is a reconfiguration of the Solar Optical Telescope (designated as ASOSOT in the original OSSA Space Station Servicing Book, November 6, 1985). This reconfiguration is designed to reduce program cost while retaining enough spatial resolution, field of view, and other features to allow the study of relevant solar structures and processes. HRSO will address fundamental problems concerning the birth, growth, and decay of the solar magnetic fields, the interaction of the magnetic fields with convective motions, the flow of mass and energy from the solar interior to the atmosphere, and the storage and release of energy by magnetic fields in explosive phenomena such as flares, surges, and coronal transients. The HRSO mission is designed to have sufficient spatial resolution to resolve the scale of basic solar physical processes, and sufficient field of view to study relevant solar structures. It also has enough spectral resolution and coverage to study specific spectral lines, shapes, and bandpasses, allowing an understanding of the composition, dynamics, and magnetic fields present in the lower layers of the solar atmosphere. The science instruments have temporal resolution of the order of seconds to allow tracking of rapid events and wave phenomena. The Coordinated Instrument Package (CIP) can carry out simultaneous observations to study complicated 3D phenomena.

1.3 HRSO Milestone and Servicing Schedule

Launch Date: TBD.

First Space Station Service: TBD.

Servicing Interval: 12 months

Operational Lifetime: 3 years

1.4 HRSO Orbital Parameters

HRSO is an attached payload.

2.0 HRSO PHYSICAL CHARACTERISTICS

2.1 HRSO Description

HRSO consists of a one-meter Gregorian telescope and a Coordinate Instrument Package (CIP). The F/24 Gregorian telescope (Figure HRSO-1) has a one meter diameter F/3.46 primary mirror, giving a 3.9 arc minute unvignetted field of view and a resolution of 0.13 arc seconds. The secondary mirror is mounted in the Gregorian pod subassembly with commandable drive actuators for focus control. The tertiary mirror deflects the beam into the CIP via an access slot to the F/24 focal plane. The HRSO mirrors are made of premium grade zerodur and coated with protected aluminum, giving a spectral range of 2200 - 10,000 A in the visible and a throughput of 0.51 m^2. [3]

The HRSO Coordinated Instrument Package is mounted externally to the telescope and is accessible without exposing the telescope optics. It consists of the following:

- Focal Plane Instrument Package (FPIP)
- Dedicated Experiment Processor (DEP)
- Power and Thermal Control Unit (PTCU)
- Image Display Unit (IDU)
- Polarization Calibration Unit (PCU)

The focal plane instruments (FPIP) will include a tunable filtergraph, a photometric filtergraph, and a visible spectrograph. The basic HRSO geometric configuration is shown in Figure HRSO-2.

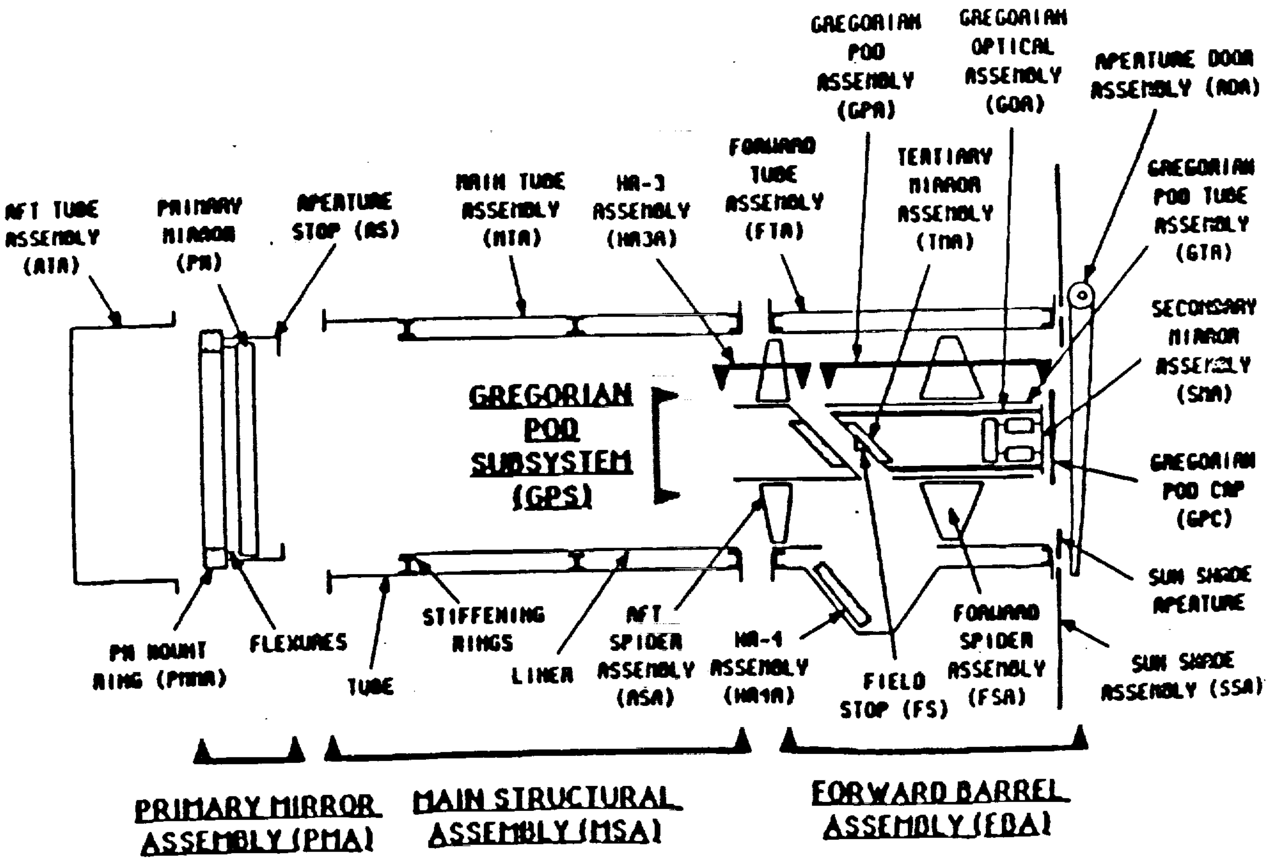

Figure HRSO-1. The HRSO Telescope

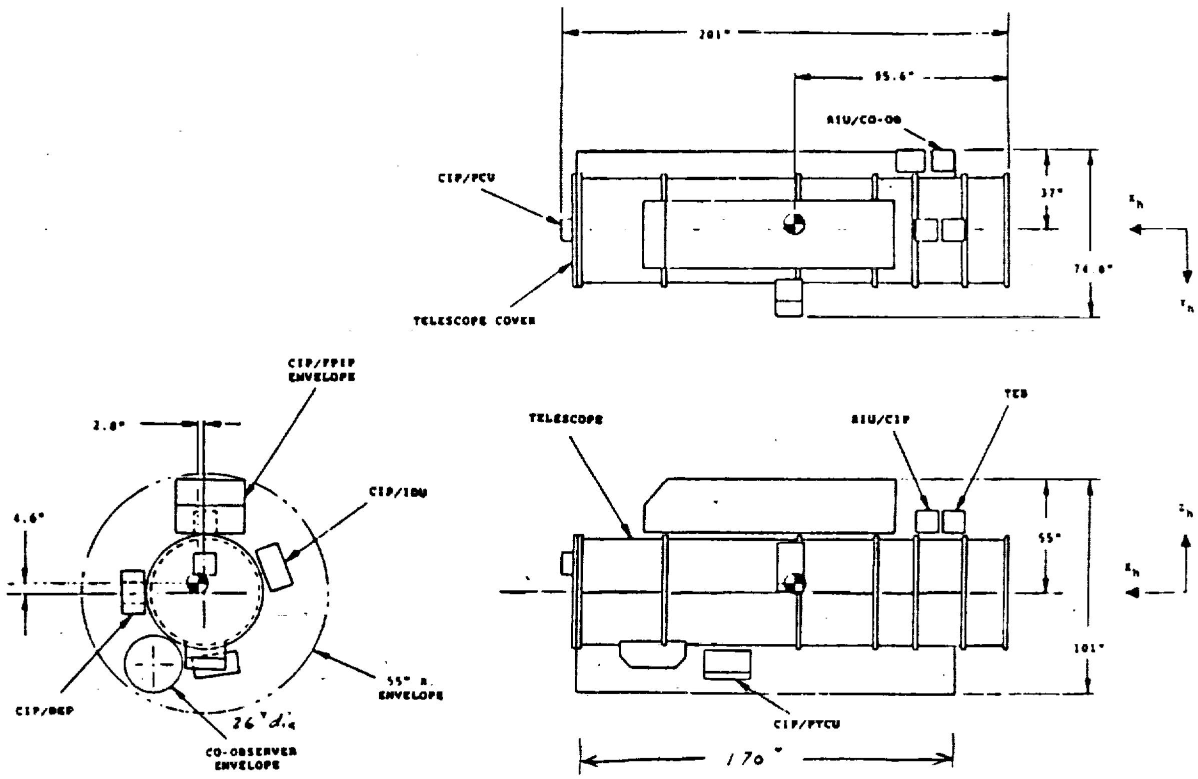

Figure HRSO-2. Basic HRSO Geometric Configuration

As an attached payload, HRSO will utilize the Space Station's Payload Pointing System (PPS) connected through a Payload Interface Adaptor (PIA) and a Station Interface Adapter (SIA) to a 2-bay truss as shown in Figure HRSO-3. The 2-bay truss is mission provided equipment (MPE). The interface between HRSO and the PPS is shown in Figure HRSO-4.

2.2 HRSO Physical Characteristics

a. Mass

- Total (wet or dry):	2234 kg (4916 lbs)
- Telescope Facility:	1098 kg (2416 lbs)
- Coordinated Instrument Package:	777 kg (1710 lbs)
- Co-Observer Instrument:	341 kg (750 lbs)
- Accessories:	18 kg (40 lbs)

See Section 9 for more detailed mass properties.

b. Envelope

- Stowed: 31.4 m^3 (5.1 x 3.8 m dia)
- Deployed: 31.4 m^3

See Figure HRSO-2 for more detail.

2.3 HRSO Moving Parts and Special Features

- Aperture door
- M4 mirror
- Filter wheels

2.4 HRSO Consumables

None.

3.0 HRSO SERVICING INFORMATION

3.1 General Description of HRSO Servicing

The only noncontingency servicing postulated for HRSO is the replacement of the co-observing external science ultraviolet instrument (See Figure HRSO-2). This changeout would take place nominally at approximately 1 year intervals.

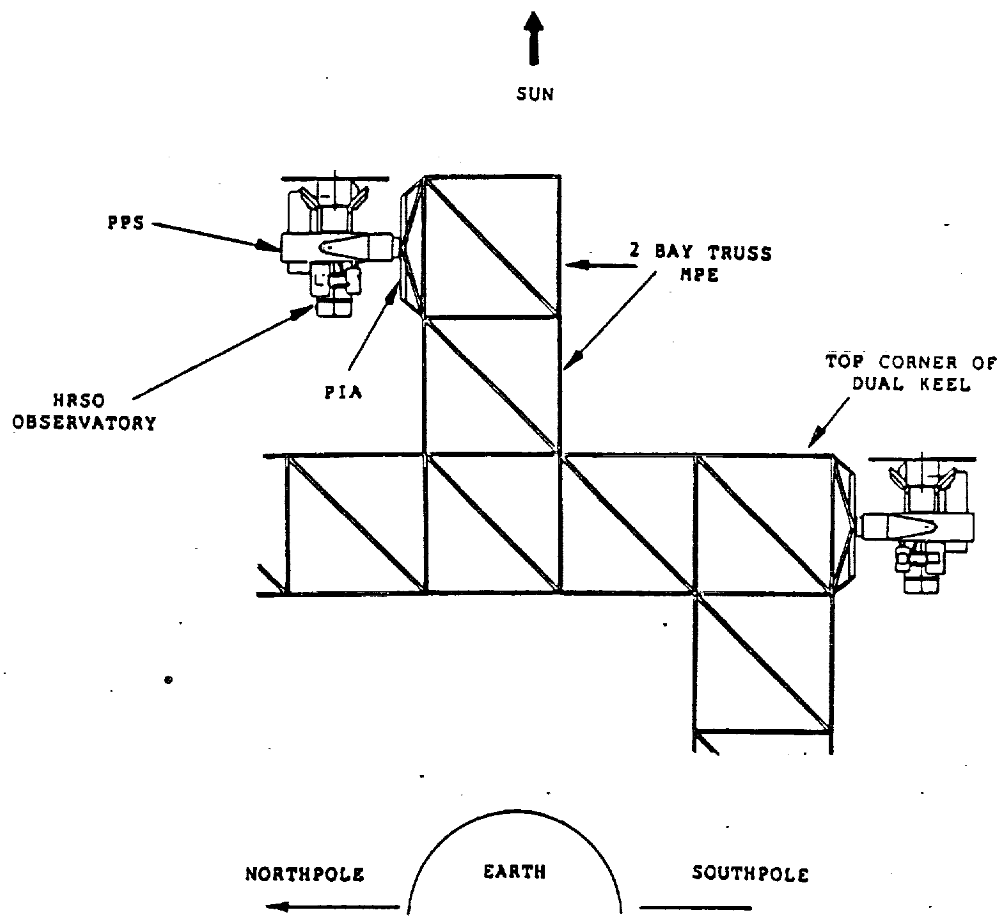

Figure HRSO-3. HRSO Observatory on PPS Aboard the Space Station

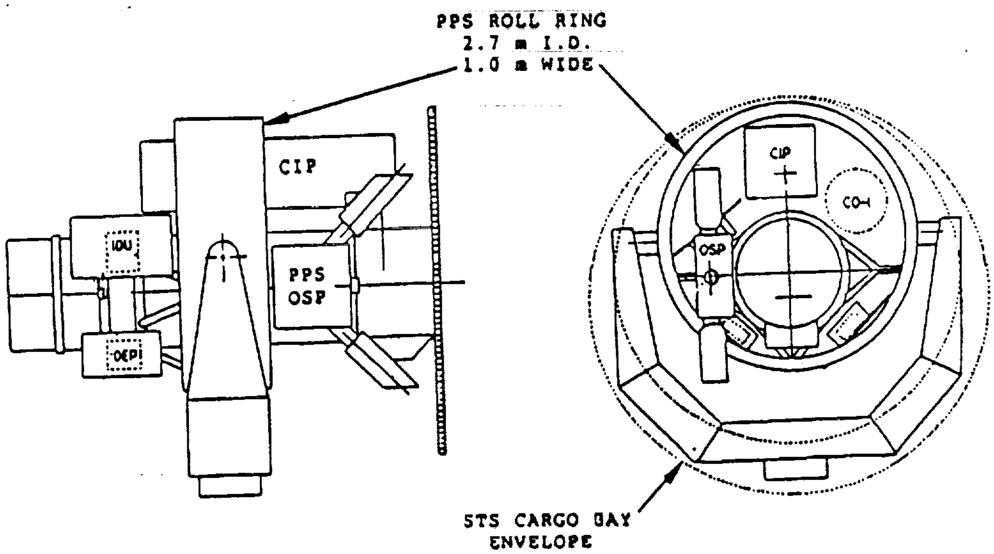

Figure HRSO-4. HRSO Configuration on the Space Station PPS

The main portion of HRSO will require servicing only in contingency situations of contamination, electronic failure, etc. No periodic telescope cleaning will be necessary. No film changeout is needed because CCD devices will be employed.

3.2 HRSO Background

HRSO was originally designed as an STS sortie payload. It has not been previously operational and has not been serviced on-orbit. Other deployment alternatives for HRSO have been investigated to various degrees, including on STS/SPACELAB, on a platform spacecraft (an Explorer platform or a retrieved Solar Maximum spacecraft), as a sun syncronous free-flyer, and as a Space Station co-orbiter.

3.3 Primary Role of Space Station in Servicing HRSO

The Space Station will provide operational support. Servicing requirements are for planned UV instrument replacement and general contingency repair or replacement.

3.4 Primary Space Station Facilities Required for Servicing HRSO

- Operating power
- Station Interface Adapter for mechanical connection
- Payload Pointing System for directional control

3.5 Space Station Personnel Required for Servicing HRSO

- Trained technicians on the Space Station
- Specialists providing support from the ground

3.6 Servicing Precautions for HRSO

None identified.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of HRSO

None; HRSO is an attached payload.

4.0 HRSO SERVICING SAFETY CONSIDERATIONS

4.1 HRSO Hazardous Systems

HRSO will have no pyrotechnic devices, volatile liquids, exotic materials, radiation sources, or pressure vessels.

4.2 HRSO Servicing Safety Precautions

No personnel safety precautions have been identified.

5.0 HRSO SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 HRSO Crew Convenience Features

Corners and edges will be rounded for crew safety.

5.2 HRSO Mechanical Interfaces

HRSO must be compatible with the Payload Interface Adapter and the Payload Pointing System's roll ring.

5.3 HRSO Umbilical Interfaces

a. Power
- 28 +1/-4 VDC.
- Servicing power TBD
- Operational power 0.8 kW excluding heaters

b. Data
- Servicing data rate TBD
- Science operational data rate 16 Mbps.

c. Fluid
- None required

5.4 HRSO RF Communciation Interface

HRSO is controlled from Earth during operation and servicing. Data and communications are handled through the SS's RF communication system.

5.5 HRSO Thermal Interface

HRSO does not need support from the Space Station thermal control subsystem. It has a nominally passive thermal control using heat

rejection mirrors, radiators, and heaters. Operational/non-operational temperature ranges are not specified.

6.0 HRSO SERVICING ENVIRONMENT

6.1 HRSO Pointing/Orientation Constraints

a. Exposure to Light

None identified.

b. Thermal Control

None identified.

6.2 HRSO Contamination Concerns

- Covering telescope when not in use.
- Heating mirrors to decrease the rate of deposition of contaminants.
- Controlling aperture door with sensor systems between HRSO and sources of contamination.

6.3 HRSO Radiation Concerns

No information available.

7.0 HRSO SERVICING ACCOMODATIONS

7.1 HRSO Equipment Access

HRSO has been designed for on-orbit servicing and a high level of equipment access. HRSO ORUs have been designed for (and are located to facilitate) replacement.

7.2 HRSO Modularity

No information available.

7.3 HRSO Automated Servicing

None identified. Robotics will be considered.

7.4 HRSO Servicing in the Space Station Pressurized Modules

None. HRSO will be serviced as an external attached payload.

8.0 HRSO SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required (Yes or No)	SS Provided (Yes or No)	Comments	Ref. Section
ORUs (including SIs)	yes	no		9.0
Flight Support Equipment	no	no		10.0
Other Equipment	no	no		10.0
Servicing Equipment Carrier(s)*	no	no		12.0
Servicing Consumables				
Propellant(s)	no	no		11.0
container(s)	no	no		11.0
Cryogen(s)	no	no		11.0
container(s)	no	no		11.0
Liquids(s)	no	no		11.0
container(s)	no	no		11.0
Gas(es)	no	no		11.0
container(s)	no	no		11.0
Other(s)	no	no		11.0
container(s)	no	no		11.0
Servicing Consumables Carrier(s)*	no	no		12.0

*Carriers for servicing materials are typically used during transportation in STS Orbiter and/or during storage on SS. A single carrier may be used.

9.0 HRSO ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of HRSO ORUs

a. Primary

The only ORU to be serviced on a planned basis is the UV co-observing science instrument.

b. Secondary

On a contingency basis the following ORUs may be replaced or repaired:

- Telescope
- Focal Plane Instrument Package (FPIP)
- Power and Thermal Control Unit (PTCU)
- Image Display Unit (IDU)
- Dedicated Experiment Processor (DEP)
- Polarization Calibration Unit (PCU)
- Telescope Electronics Box (TEB)

9.2 HRSO ORU Physical Characteristics

Table HRSO-1 is a mass property list for HRSO. It includes all ORUs identified in Section 9.1, and provides data on some additional items to bring the total mass to the previously identified observatory mass of 2234 kg. Mass, dimensions, and quantity are provided.

9.3 HRSO ORU Storage Requirements

Not applicable. Requirements for contingency storage are TBD.

9.4 Other Environmental Requirements for HRSO ORUs

No information available.

Table HRSO-1. HRSO Mass Property List

ITEM	MASS (kg)	VOLUME (m^3)	DIMENSIONS (in)	DIMENSIONS (m)	QUANTITY	ORU	NOTES
1. Telescope	1048	5.75	48 dia x 194	1.22 dia x 4.93	1	yes	
2. CIP/FPIP Envelope	596	1.43	31 x 25 x 113	.79 x .64 x 2.87	1	yes	(1)
3. CIP/PTCV	80	.07	20 x 10 x 20.5	.51 x .25 x .52	1	yes	(1)
4. CIP/IDV	50	.04	20 x 10 x 11.5	.51 x .25 x .29	1	yes	(1)
5. CIP/DEP	42	.04	20 x 10 x 12.5	.51 x .25 x .32	1	yes	(1)
6. CIP/PCV	9	.01	10 x 10 x 5	.25 x .25 x .13	1	yes	(1)
7. TEB	5	.02	10 x 10 x 10	.25 x .25 x .25	1	yes	
8. RIV/CIP	9	.02	10 x 10 x 10	.25 x .25 x .25	1	no	(2)
9. RIB/CO-OB	9	.02	10 x 10 x 10	.25 x .25 x .25	1	no	(2)
10. Co-Observer Envelope	341	1.48	26 dia x 170	.66 dia x 4.32	1	yes	Science Instrument
11. Cover	45	.07	52 dia x 2	1.32 dia x .05	1	no	
TOTAL	2234						

(1) The preface "CIP/" indicates membership in the Coordinated Instrument Package

(2) RIU indicates "Remote Interface Unit"

10.0 HRSO FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 HRSO Flight Support Equipment (FSE)

HRSO FSE is expected to be minimal. Little or no mission-unique tooling or cabling should be required.

10.2 HRSO FSE Physical Characteristics

TBD.

10.3 HRSO FSE Storage Requirements

TBD.

10.4 Miscellaneous Servicing Equipment

TBD.

11.0 HRSO SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

HRSO has no consumables.

11.2 Physical Characteristics

Not applicable.

11.3 Storage Requirements

Not applicable.

12.0 CARRIERS FOR PAYLOAD SERVICING MATERIALS

12.1 Description of Carriers

TBD.

12.2 STS and SS Carrier Interfaces

TBD.

12.3 Servicing Materials/Carrier Interfaces

TBD.

13.0 HRSO ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

No information available.

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unloading servicing material from STS to SS	0:30^	0:30^	0:00^	0:30^
2. Transport Servicing Material To HRSO	1:30^	1:30^	3:00^	1:30^

13.3 Principal Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. S.I. changeout	3:00^	4:30^	6:00^	1:30^

13.4 Closeout Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Transport servicing material from HRSO	1:30^	1:30^	3:00^	1:30^
2. Loading of servicing material from SS to STS	0:30^	0:30^	0:00^	0:30^

14.0 HRSO STRAWMAN SERVICING SCENARIO

14.1 HRSO STRAWMAN SERVICING MISSION

Only one strawman mission (strawman A) is defined for HRSO. It consists of the replacement of the co-observing UV science instrument on a yearly basis.

14.2 HRSO Description

HRSO's servicing configuration is the same as its operational configuration (see Figure HRSO-3). Its mass is 2234 kg, its volume 31.4 m^3, and its overall dimensions are 5.1 x 3.8 m dia (201" x 110" dia).

14.3 Strawman Servicing Materials

a. ORUs

The relevant ORU (UV co-observer) has the following properties:

Quantity	Mass (kg)	Volume (m^3)	Power (kW)
1	341	1.48	TBD

b. FSE

Flight Support Equipment is minimal. Its mass is estimated to be zero.

c. Consumables and Containers

Not applicable.

d. Carrier(s)

Carrier information is TBD. The mass and volume of the carrier may be estimated using the equations described in Appendix C and summarized in Appendix D. Thus from Appendix D, Page 4, the mass of the carrier is assumed to be (.57) (341 kg) = 194 kg and the corresponding volume is (1.16) (1.48 m^3) = 1.72 m^3.

14.4 Estimated Up/Down Mass on STS to Support HRSO Strawman Servicing

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	341	0	341
ORU(s)	0	0	0
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	341	0	341
Equipment Carrier(s)	194^	0	194^
Subtotal, Equipment Mass Up	535^	0	535^
Subtotal, Equipment Mass Down	535^	0	535^
Consumables			
Consumables	0	0	0
Consumables Containers	0	0	0
Consumables Containers' Carriers	0	0	0
Subtotal, Consumables Mass Up	0	0	0
Subtotal, Consumables Mass Down	0	0	0
Total Mass Up	535^	0	535^
Total Mass Down	535^	0	535^

14.5 Estimated Up/Down Volume (m^3) on STS to Support HRSO Strawman A Servicing

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	1.5	0	1.5
ORU(s)	0	0	0
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	1.5	0	1.5
Equipment Carriers	1.7^	0	1.7^
Equipment and Carriers Subtotal	3.2^	0	3.2^
Consumables			
Consumables	0	0	0
Consumables Containers	0	0	0
Consumables Containers Carriers	0	0	0
Total Volume Up	3.2^	0	3.2^
Total Volume Down	3.2^	0	3.2^

14.6 Storage on Space Station Required to Support Strawman HRSO A Servicing

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	0	0	0
Volume (m^3)	0	0	0
Average Power (Watts)	0	0	0
Temperature Range (^oC)	N.A.	N.A.	N.A.
Temporary Storage			
Mass (kg)	535^	0	535^
Volume (m^3)	3.2^	0	3.2^
Average Power (watts)	TBD	N.A.	TBD
Temperature Range (^oC)	TBD	N.A.	TBD

14.7 HRSO Strawman Servicing Power Estimates

	Operational Mode (Watts)		Servicing Mode (Watts)	
	AVG	MAX	AVG	MAX
Payload (Bus + Instruments)	800	TBD	TBD	TBD

Note: Average operational power given excludes heater power.

14.8 HRSO Strawman A Servicing Times

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unloading servicing material from STS to SS	0:30^	0:30^	0:00^	0:30^
2. Transport servicing material to HRSO	1:30^	1:30^	3:00^	1:30^
3. ORU changeout	3:00^	4:30^	6:00^	1:30^
4. Transport servicing material from HRSO	1:30^	1:30^	3:00^	1:30^
5. Loading of servicing material from SS to STS	0:30^	0:30^	0:00^	0:30^
TOTALS	7:00^	8:30^	12:00^	5:30^

14.9 OMV Flights in Support of HRSO Strawmen Servicing Mission

None required; HRSO is an attached payload in this study.

15.0 SUMMARY OF OVERALL REQUIREMENTS FOR SERVICING OF HRSO AT SPACE STATION

15.1 HRSO Milestones and Servicing Schedule (Nominal Mission Model)

Event	Location	Date	Comment
Payload Launch	STS/ETR	TBD	
1st Servicing	SS	TBD + 1 year	Strawman A
2nd Servicing	SS	TBD + 2 years	Strawman A
Payload Mission Termination		TBD + 3 years	

15.2 Summary of HRSO Mass Considerations

a. HRSO Mass (Operational and During Servicing)

HRSO Mass (dry):	2234 kg
Consumables Mass:	0 kg
HRSO Mass (total):	2234 kg

b. HRSO Servicing Materials Mass Up and Down in STS

Event	Mass Up (kg)	Mass Down (kg)
Launch	TBD*	
1st Servicing	535^	535^
2nd Servicing	535^	535^
Payload Mission Termination		TBD*
Totals	TBD	TBD
Servicing Totals	1070^	1070^

*Mass Up/Down will include TBD mass of PPS ring and appropriate cradle.

c. HRSO Servicing Storage Mass on Space Station

Years from Launch	0	1	2	3
Storage Mass (kg)	0	535^	535^	0
Unpressurized	0	0	0	0
Total	0	535^	535^	0

15.3 Summary of HRSO Volume Considerations

a. HRSO Volume

Operational Configuration:	31.4 m^3
Servicing Configuration:	31.4 m^3
Storage/Transportation Configuration:	31.4 m^3

b. HRSO Servicing Volumes Up and Down in STS*

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	TBD	
1st Servicing	3.2^	3.2^
2nd Servicing	3.2^	3.2^
Payload Mission Termination		TBD
Totals	TBD	TBD
Servicing Totals	6.4^	6.4^

*Excludes initial payload launch volume and mission termination flight volume, both chargeable to payload operations.

c. HRSO Servicing Storage Volume on Space Station

Years Since Launch	0	1	2	3
Storage Volume (m^3)				
Unpressurized	0	3.2^	3.2^	0
Pressurized	0	0	0	0
Total	0	3.2^	3.2^	0

15.4 Summary of HRSO Power Considerations

	AVG	MAX
Operational Power (watts)	800*	TBD
Servicing Power (watts)	TBD	TBD
Storage Power, Servicing Materials (watts)	TBD	TBD

*800 watts does not include heater power.

15.5 Summary of HRSO Servicing Time Estimates

Years Since Launch	0	1	2	3
Elapsed Time (hr:min)	0	7:00^	7:00^	0
IVA Time (Crew-hr:min)	0	8:30^	8:30^	0
EVA Time (Crew-hr:min)	0	12:00^	12:00^	0
Total Crew Time (Crew-hr:min)	0	20:30^	20:30^	0
Robotics Time (hr:min)	0	5:30^	5:30^	0

15.6 Summary of OMV Flights in Support of HRSO Servicing

Not applicable.

REFERENCES

1. Interview with Mr. James Barrowman, GSFC (August 12, 1987).

2. Interview with Mr. Michael Comberiate, GSFC (March, 1987).

3. Telephone conversation with Mr. Chi Wu, OAO Corporation (September 30, 1987).

4. Mission Requirements Data Base (MRDB), NASA/JSC, January 17, 1987.

5. Operations Scenarios: ASTROMAG, AXAF, HRSO, SIRTF, HST and GRO (Draft), The BDM Corporation, November, 1986.

HUBBLE SPACE TELESCOPE (HST): MISSION CODE SAAX0012

1.0 HST PROGRAM AND OPERATIONS INFORMATION

1.1 HST Points of Contact

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1.2 HST Objectives

HST will study the character and evolution of planets, stars, galaxies, pulsars, quasars, neutron stars, black holes, gas clouds, and the universe. HST allows the viewing of objects 14 billion light years away, which is seven times the distance observable with Earth's best observatories.

1.3 HST Milestone and Servicing Schedule

Launch Date: 3rd quarter, 1989.
First Space Station Service: 3rd quarter, 1998.
Servicing Interval: 18 to 22 months.
Operational Lifetime: 15 years.
Note: HST is serviced by the STS in 1992 and 1995.

1.4 HST Orbital Parameters

- Free-Flyer.
- 600 km circular orbit at release.
- 28.5 degrees inclination.
- Orbital period of approximately 95 minutes.
- Altitude losses are corrected by an OMV reboost after maintenance service.

2.0 HST PHYSICAL CHARACTERISTICS

2.1 HST Description

a. Comments

HST is a free-flying celestial pointer. Spacecraft equipment is identifiable as belonging to one of three areas: (See Figure HST-1).

(1) The Optical Telescope Assembly (OTA).

(2) The Science Instruments (SIs).

(3) The Support Systems Module (SSM).

b. Optical Telescope Assembly (OTA) (See Figure HST-2)

- 2.4 meter reflecting Cassegrain telescope mirror.
- Graphite/epoxy metering truss.
- Focal plane instrument structure.
- OTA equipment section (OTA ES): Nine bays containing OTA and fine guidance sensor electronics.
- Main ring.
- Main and central baffles.
- Secondary mirror baffle and assembly.

c. Science Instruments (SIs, 5 total) (See Figure HST-1)

- Radial: Wide field/planetary camera (WF/PC).
- Axial: Faint object spectrograph (FOS); high resolution spectrograph (HRS); high speed photometer (HSP); faint object camera (FOC).

d. Support Systems Module (SSM) (See Figure HST-3)

- Light shield (LS).
- Aperture door (AD).
- Forward shell (FS).
- SSM equipment section (SSM ES).
- Aft shroud including aft bulkhead (AS/AB).

2.2 HST Physical Characteristics [37]

a. Mass

- Dry: 11600 kg
- Wet: N.A.

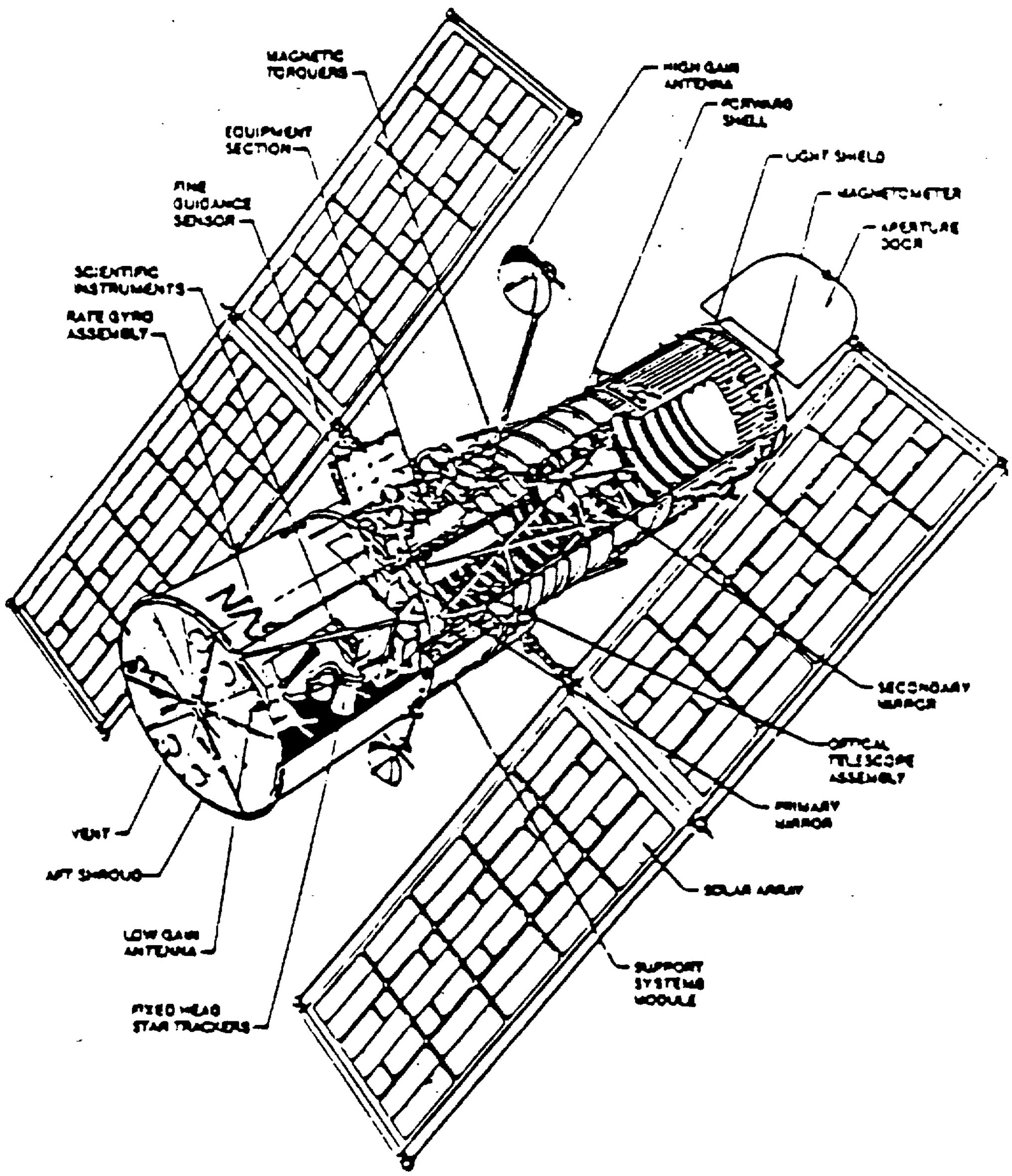

Figure HST-1. Hubble Space Telescope (33)

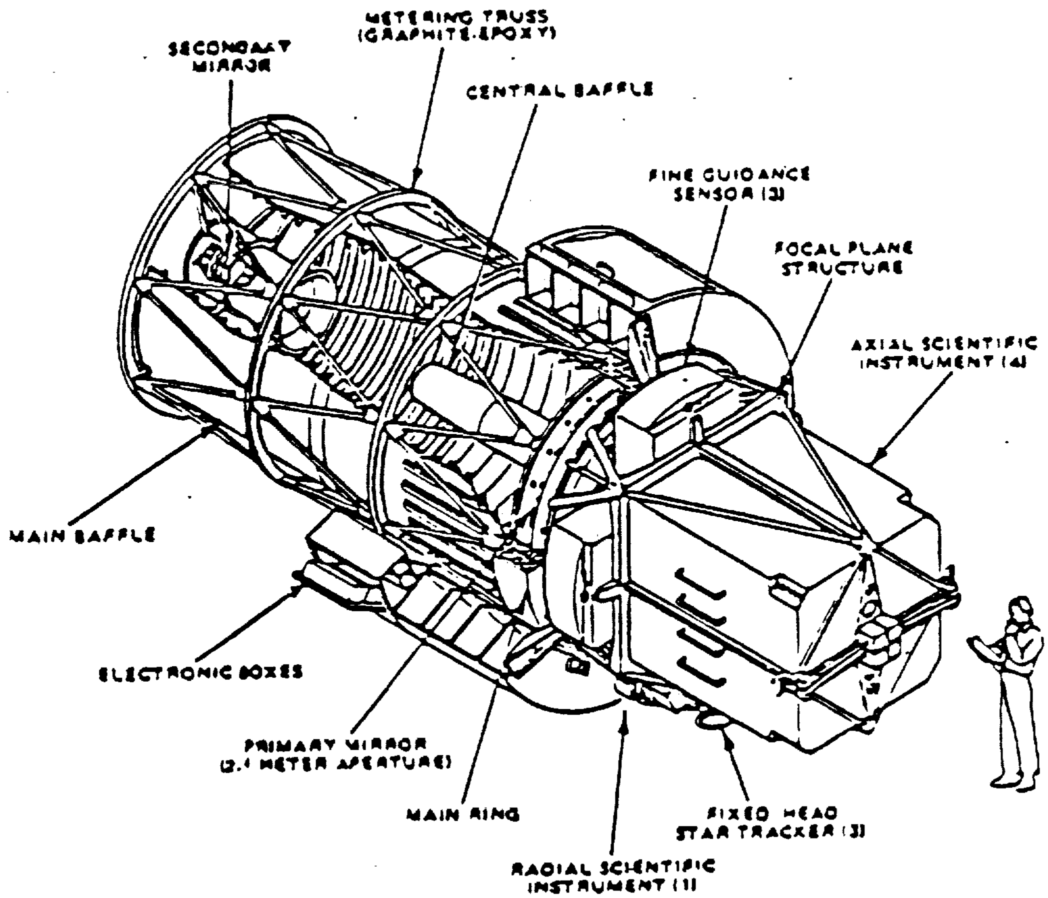

Figure HST-2. Optical Telescope Assembly (33)

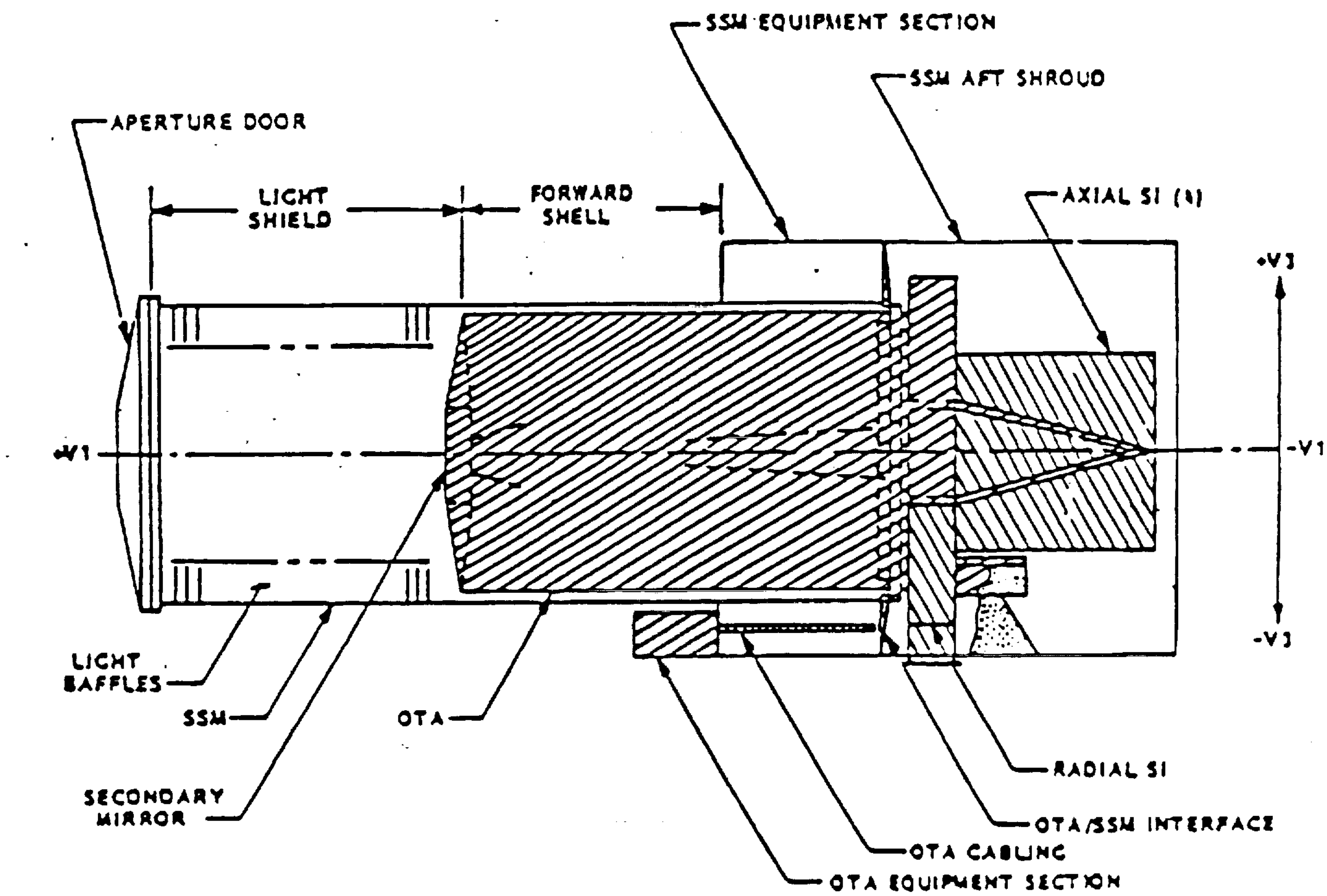

Figure HST-3. Support System Module (33)

b. Dimensions

- Length:	13.1 m
- Equipment section and aft shroud:	5.1^ x 4.3 m dia
- Light shield and forward shell:	8.0^ x 3.0 m dia
- Solar arrays (2): (deployed)	2.5 x 12.2 x 0.4 m
(retracted)	2.5 x 0.4 m dia
- Solar array booms:	2.3^ m
- High gain antennas (2):	1.3 m dia
- High gain antenna booms:	4.0 m
- OTA aperture door (AD):	3.0 x 3.0 m

c. Envelope

- Stowed:	13.1 x 4.3 m dia
- AD Open, SAs deployed to OTA:	12.3 x 12.6 x 16.1 m

2.3 HST Moving Parts and Special Features

a. Notes About Latches [33]

- Latches are normally operated with a rotary drive actuator, but contingency manual operation is also available.

b. Notes About Hinges [33]

- The control system governing hinge action may be overridden by exerting forces great enough to overcome those of the hinge.

c. Solar Arrays (SA) [33]

- Single gimbal, roll-out blanket arrays; deployed position shown in Figure 1.
- 4 latches per SA: 2 latches located at the SA aft position, 2 latches located at the forward position.

d. High Gain Antennas (HGA) [33]

- Two latches are used on each of the two HGAs.
- Hinges are also used in HGAs.
- Each HGA utilizes one two-axis-gimbal (TAG).

e. Optical Telescope Assembly (OTA) Aperture Door (AD) [33]

- Secured by two hinge drives and one latch.
- The aperture door is not light-tight. A 3-cm gap remains between the door and the OTA when the AD is in the closed position.

2.4 HST Consumables

No consumables are required by HST's present configuration. However, future replacement IR SIs will require cryogens to cool the detector. Plans for this future cryogen replacement should be made at the Space Station. The type of cryogen and the amount to be replenished in the future are TBD.

3.0 HST SERVICING INFORMATION

3.1 General Description of HST Servicing

HST will be serviced by the STS in 1992 and 1995 - a three year servicing interval. HST plans on being serviced at the Space Station starting in 1998. A station based OMV will be required for HST retrieval and redeployment/reboost.

The servicing interval for HST at the SS is constrained by the laws of orbital mechanics. Because SS and HST have different operational altitudes, their orbital nodes precess at different rates. This differential precession rate results in the orbital planes re-aligning every 18-22 months (exact values are altitude dependent). Thus, servicing will not occur at the 3 year intervals mentioned above. Also, this differential precession rate leaves only a 3 week window during which servicing may occur based on the OMV's limited orbital plane-change capability and HST's mass.

Conditions which warrant servicing include: 1) normal degradation -batteries, solar arrays, rate gyros, orbital decay; 2) random equipment failure -electronic and mechanical components; 3) SI replacement and upgrade. Statistical studies,

predicting the failure of HST equipment, underlie the planned servicing missions. HST systems are modularly designed to ease servicing; dual and triple redundancies are incorporated to reduce the operational impact and reduce the requirement for rapid response missions. Planned servicing consists only of changeout activities for designated ORUs at this time.

Prior to OMV transport, both before and after servicing, HST is configured to its retrieval/predeployment ready configuration: 1) SIs and SIC&DH switch to safe or hold mode; 2) FGE and FGS switch to hold or standby mode; 3) the aperture door is closed and latched; 4) HGAs are retracted and latched; 5) the -V1 direction (the aft shroud, see Figure 3) is pointed toward the sun. [51]

Following its release into orbit, the HST will be fully exercised by ground control. [9] The OMV may need to recapture HST during this exercise period of TBD length if systems are not operating satisfactorily. [9,10]

3.2 HST Background

HST is a new spacecraft, which will strive for a 15-year operational lifetime goal through on-orbit servicing. HST is the first observatory designed for extensive maintenance and refurbishment.

3.3 Primary Role of Space Station in Servicing HST

Maintenance and upgrade of HST instruments and subsystems comprise the planned SS servicing activity. Current expectations include replacement of failed Orbital Replaceable Units (ORUs) and replacement of SIs with either different or upgraded SIs. Future requirements may also include the replenishment of cryogens for advanced upgraded infra-red (IR) SIs.

Statistical reliability studies for STS based servicing have been performed on HST's various subsystems and components. From these

studies, the anticipated servicing schedule broken down into components follows: [38]

Every 3 years: Six nickel-cadmium or nickel-hydrogen batteries
SIC&DH
Fine Guidance Sensor and Electronics
Rate Gyro Assembly
DF-224 Computer.

Every 6 years: Reaction Wheel Assembly
Multiple Access Transponder.

Every 9 years: Engineering/Science Tape Recorder
Data Interface Unit.

Every 12 years: Solar Array Drive Electronics
Magnetic Torquer Electronics (part of PSEA).

3.4 Primary Space Station Facilities Required for Servicing HST

- Sun shield or shroud for thermal control to nonoperational temperature range (worst case) of 4 to 20° C. [37]
- RMS arm to grapple and transfer HST to berthing location. [37]
- Contamination control. [37]
- Temperature-controlled environment for storage of ORUs and user-provided equipment. [37]
- 1.7 kW power available during servicing, 28 V DC. [3] Reference [47] describes the DC power ripple, transients, and common-mode voltage requirements for power supplied by SS during HST servicing. In addition, this reference specifies the magnetic and electric field environments acceptable.
- The design of the HST maintenance area shall preclude any electrostatic discharges. [47]
- Equivalent of flight support system (FSS) interface for berthing. [37]

- FSS platform or SS-equivalent (See Section 10.1 for a more-detailed description of this SS-provided facility).
- Space Station-based OMV for HST retrieval and reboost. [37]

3.5 Space Station Personnel Required for Servicing HST

All servicing will be performed by 3 crew payload servicing mission-specialists advised by HST SI or subsystem specialists on the ground. Major repair of electronics is not planned. One mission-specialist must be trained in: FSS-equivalent and RMS

operation, ORU components, and operations and support equipment. The other two mission-specialists serve as EVA astronauts with knowledge of the ORU-related activities. All mission-specialists must be trained in contamination control procedures. [24]

3.6 Servicing Precautions for HST

- Install covers on WF/PC and Axial SI's radiators.
- Install covers on FGS, star trackers, and HGAs.
- Install handhold plate assembly on WF/PC and FGS.
- The aperture door (AD) should remain closed during servicing to protect the OTA from contaminants and light.
- High gain antennas will be stowed for retrieval and servicing but may be deployed during checkout at SS.
- Solar arrays are extremely fragile. Their design permits multiple deployments and retractions, but this may seriously degrade the blankets. Partial retraction is possible.
- No servicing tools which outgas or shed particulate matter are allowed inside the aft shroud.
- There should be no impact with the aft shroud/SSM/OTA doors during EVA operations. Damage could prevent the doors from closing. [5]
- RWAs must be completely spun down to a complete stop before EVA changeout. [5]
- Avoid RF transmissions during EVA. HST must be protected from direct-beam Ku-band radiation at all times. [5]

- Verify that power is off to all ORUs to be serviced before each ORU EVA activity. [5]
- Velcro fasteners shall not be used for EVA tools due to high particulate generation; only tethers are acceptable. Velcro elsewhere on HST and the EMU should be minimized. [9]
- Never touch electrostatic discharge (ESD) sensitive components unless they are sufficiently grounded.
- HST should always be warmer than other materials or structures in the area to discourage condensation on HST. [47]

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of HST

The OMV retrieves the HST for servicing and then returns it, when required, to its 600 km circular orbit after servicing. Before returning to the SS, the OMV waits for HST checkout in case of HST redeployment malfunction. The length of time for this checkout is TBD.

HST does not require power from the OMV during transport as HST remains in retrieval/redeployment ready configuration during OMV transport. (See Section 3.1)

4.0 HST SERVICING SAFETY CONSIDERATIONS

4.1 HST Hazardous Systems

- Battery electrolyte is a hazardous material. [8]
- The Maintenance and Refurbishment Space Support Equipment (M&R SSE) are designed with: [39]
  * No pyrotechnic devices.
  * No propulsion system.
  * No pressurized systems.
  * No energy storage devices (other than the 6 ORU batteries).

4.2 HST Servicing Safety Precautions

None specified.

5.0 HST SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 HST Crew Convenience Features

- Handrails and handholds on the outer structure.
- Handrails and handholds within the SSM and SI compartments.
- Portable handhold I/F plates on the SIs and larger ORUs.
- Portable foot restraints and manipulator foot restraints.
- Tether rings.
- Internal portable lighting sockets within the SSM and SI compartments.
- Axial SI, FGS, WF/PC installation guides.
- Slotted holes, capture washers/bolts, alignment guides, identification marking, connector alignment markings, connector maps, access doors, wing tab connectors.
- Remote astronaut control panel (power) for EVA.

5.2 HST Mechanical Interfaces

- 2 RMS grapple fixtures.
- 3 FSS berthing pins of the aft bulkhead.

5.3 HST Umbilical Interfaces

a. Power

- 28 V DC.
- 1.7 kW required for servicing.
- 2.7 kW required for 7 minutes during servicing peak [3].
- 2.1 kW during operation [3].
- The automatic disconnect mechanism used with both HST umbilicals requires 115 V AC (400 Hz, 0.3 A) for 3 seconds to operate.
- 2 connector I/F locations on aft bulkhead:

Primary Connector: Since HST will be serviced first from the STS, this connector is designed for that mission. The HST maintenance platform (MP), used for STS servicing, contains a motor-driven umbilical which mates to the primary connector. This umbilical is designed for automatic connect/disconnect, and supplies power only. The umbilical may also be connected or disconnected by EVA if the automatic system malfunctions. [33]

Secondary Connector: If the primary connector is damaged, then the HST deploy/return connector (normally employed during launch or return to ground) can be used. The umbilical which mates to this connector is currently configured for EVA connection with automatic disconnect. [33]

b. Data
HST has no signal or data interface via hardlines. CMD, TLM, and SI data interfaces via RF only.

c. Fluid
Intake quick disconnect fittings for dry nitrogen purge on aft bulkhead for future-SI requirements. These supply purge GN_2 to three of the four axial SIs and the WF/PC.

5.4 HST RF Communication Interface

a. Operational Forward Link (TDRSS to HST)
- Employs low gain antennas.
- CMD rates of 125/1000 bps.

b. Operational Return Link (HST to TDRSS)
- Employs high gain antennas.
- 5 watt minimum output from multiple access transmitters (MAT). Typical modulation frequencies are 4 kbps and 32 kbps. Center frequency of 2287.5 MHz. Pseudorandom noise at 3 MHz with pulse width 0.33 microseconds. [8]

- 13.5 watts minimum (15 watts actual) output from SSA transmitters. Typical modulation frequency 1.024 Mbps times 3 (equals 3.072 Mbps). Center frequency 2255.5 MHz with pulse width of 0.325 microseconds. [8]
- Contingency mode allows transmission through the LGAs at 500 bps.

c. SS-Servicing Communications

- A communication link via a payload-interrogator (PI) type interface (Orbiter-equivalent) is needed at the SS.

5.5 HST Thermal Interface

- HST employs passive thermal control augmented by heaters.
- The SSM ES bays radiate about 200 watts (average) during HST operation. Temperature sensors will operate heaters to maintain thermal equilibrium when HST is non-operative.
- HST SIs are extremely temperature-sensitive and must be shrouded or shaded when removed from the HST. SIs cannot be exposed to direct sunlight.

6.0 HST SERVICING ENVIRONMENT

6.1 HST Pointing/Orientation Constraints

a. Exposure to Light

HST exposure to the sun shall not exceed the time limits for all attitudes and conditions shown in Figure HST-4 for all activities.

b. Thermal Control

The orientation of HST is critical for efficient thermal control. Nominally, when serviced at the Orbiter, the sun should lie in the V2-V3 plane, and the sunline should be within 5 degrees (up to 30 degrees for not more than 7.5 hours) of the +V3 axis. If external power is not provided, and HST is in an adverse orientation, the batteries will begin to degrade within two hours.

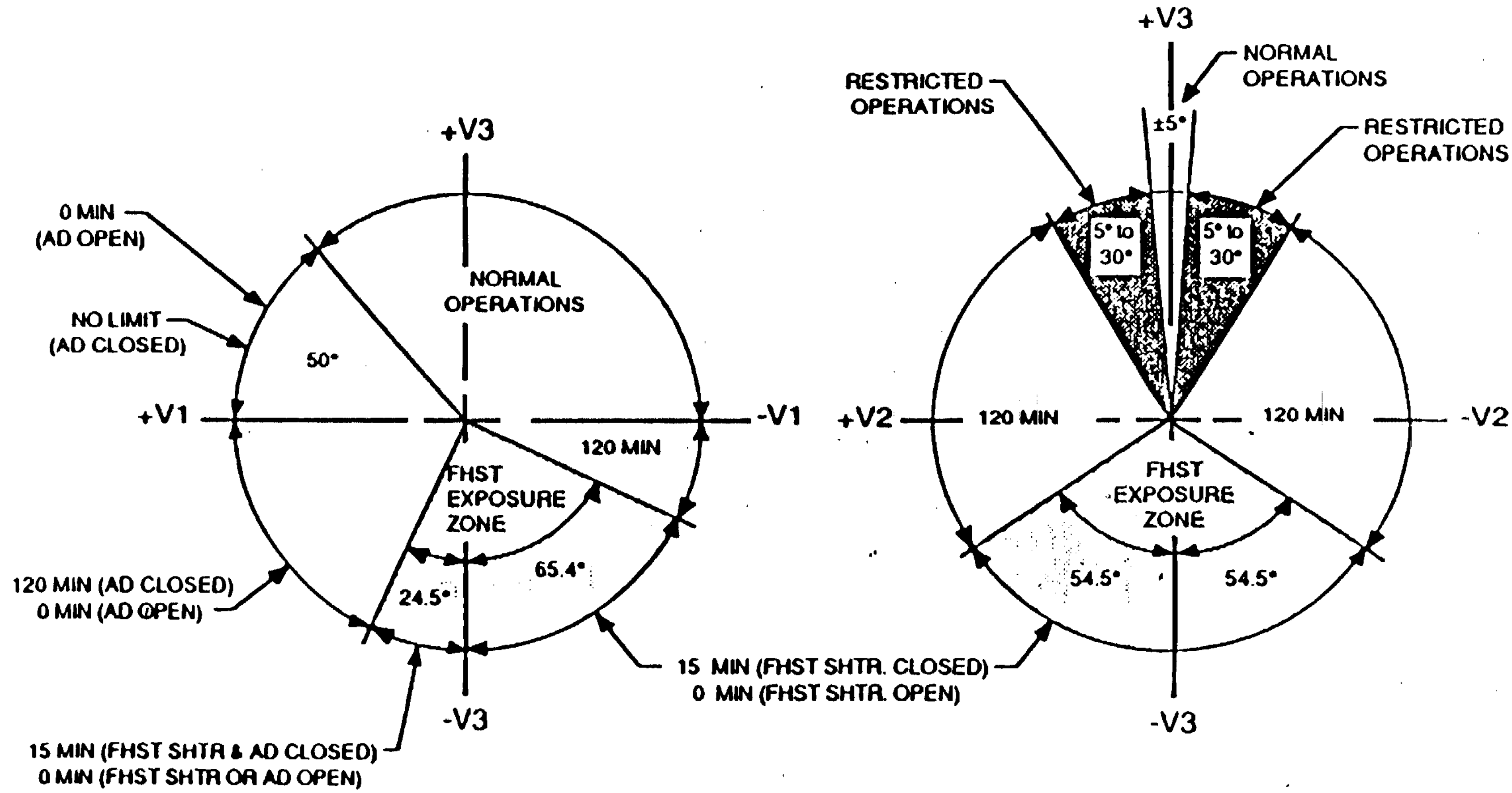

Figure HST-4. HST Sun Exposure Time Limits (8)

6.2 HST Contamination Concerns

- HST optical surfaces are extremely sensitive to molecular contaminants and small particles. The most contamination sensitive region of the HST is the 3 cm gap between the closed aperture door and the light shield. [8]
- HST is sensitive to water vapor contamination. [9]
- Inert propellants only (no combustibles) in vicinity of HST.
- Gas pressure must be less than 1.0E-5 torr prior to SI, FGS, or star tracker power-up.

6.3 HST Radiation Concerns

- SIs and OBC are sensitive to effects of the South Atlantic Anomaly (SAA) when operating. This may restrict checkout/test operations following servicing.
- At all times, HST sun exposure must fall below the limits described in Figure HST-4. [9]
- HST must be protected from Ku-band direct-beam radiation at all times. [9]

7.0 HST SERVICING ACCOMMODATIONS

7.1 HST Equipment Access

- HST has been designed for on-orbit servicing with a high level of equipment access. All HST SIs and ORUs have been designed for and are located to facilitate EVA replacement.
- The radial SI (WF/PC) is mounted on its access door which is also the WF/PC radiator. The door is 0.79 X 2.03 meters.
- Each axial SI access door is 2.03 x 2.54 meters.
- Each FGS access door is 0.76 x 1.52 meters.
- The SSM ES is accessed by 8 doors; each is 1.27 x 1.55 m.
- The OTA ES is accessed by 9 doors; each 0.51 x 0.91 m.
- Some SSM and OTA ORUs are mounted on their access door.

7.2 HST Modularity

HST has been designed from inception for extensive on-orbit servicing. There is also an on-going effort to qualify

additional HST components as ORU's for on-orbit servicing. This effort has lead to the definition of three categories, or "blocks", of specific ORU's. Block 1 ORU's are those items, including the Science Instruments which were originally desginated as ORU's. Block 2 defines the set of components which have been redesignated as ORU's after having been subjected to neutral buoyancy tank simulations and design modifications in order to qualify. The last category, Block 3, contains a set of components which were originally designated for ground replacement, but are now being evaluated for upgrade to formal ORU status.

70 ORUs have been identified, 47 of which are Block 1 and 23 of which are Block 2. An additional 22 non-ORUs designated for upgrade to ORU status are contained in Block 3. HST ORUs, are configured with standard tool interfaces, handles, captive fasteners, etc. All ORUs are shelf-mounted with the exception of SIs, FGSs and SAs. [40]

7.3 HST Automated Servicing

The effect of automated servicing has not been determined. Both IV and EV activity, accomplished in parallel, determine the servicing time estimates. The impact of reducing EV activity by automated servicing is TBD.

Systems and components affected by planned servicing are modularly designed and thus could be candidates for eventual automated servicing.

7.4 HST Servicing in the Space Station Pressurized Modules

Planned servicing missions require only the replacement of modular components. No requirements for pressurized servicing exist.

8.0 HST SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Comments	Ref. Section
ORUs (including SIs)	Yes	No	5 SIs	9.0
Flight Support Equipment	Yes	Yes	FSS to be SS-supplied	10.0
Other Equipment	No	No		10.0
Servicing Equipment Carrier(s)	Yes	No		12.0
Servicing Consumables				
Propellant(s)	No	No		11.0
container(s)	No	No		11.0
Cryogen(s)	No	No		11.0
container(s)	No	No		11.0
Liquid(s)	No	No		11.0
container(s)	No	No		11.0
Gas(es)	No	No		11.0
container(s)	No	No		11.0
Other(s)	No	No		11.0
container(s)	No	No		11.0
Servicing Consumables Carrier(s)	No	No		12.0

9.0 HST ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of HST ORUs

A system simulation analysis indicated the equipment most likely to fail and/or require replacement during a 15-year mission. The "top 20" of these service-demanding items are listed below, in order, starting from the highest failure-rate equipment. [38]

*	SI Control and Data Handling	: SIC&DH
*	DF-224 Computer	: DF224
*	Rate Gyro Assembly	: RSU & ECU
*	Fine Guidance Electronics	: FGE
+	Data Management Unit	: DMU
	Scientific Instruments	: SIs(listed below)
	*Faint Object Camera	: FOC
	*Faint Object Spectrograph	: FOS
	*High Resolution Spectrograph	: HRS
	*High Speed Photometer	: HSP
	*Wide Field Planetary Camera	: WF/PC
*	Fine Guidance Sensors	: FGS
*	Reaction Wheel Assembly	: RWA
+	Multiple Access Transponder	: MAT
+	Engineering/Science Tape Recorders	: ESTR
+	Data Interface Unit	: DIU
+	Solar Array Drive Electronics	: SADE
@	Magnetic Torquer Electronics (Part of PSEA)	: PSEA
@	Fixed Head Star Tracker	: FHST
*	Batteries	: BAT
+	Power Distribution Unit	: PDU
@	Power Control Unit	: PCU
@	Charge Current Controller	: CCC
+	Single Access Transmitter	: SAT
+	Electrical Power/Thermal Cond. Elec.	: EP/TCE

Note: * denotes Block I ORU
+ indicates Block II ORU
@ denotes Block III ORU

The following equipment will also statistically require servicing during a 15 year mission:

@	Actuator Control Electronics	: ACE
*	Diode Box Assembly	: DBA
*	Fuse Plug	: FP
@	Gimbal Electronics Assembly	: GEA
@	Instrumentation and Control Unit	: ICU
@	Low Gain Antenna	: LGA
+	Mechanism Control Unit	: MCU
@	Magnetometer	: MSS
@	Magnetic Torquer	: MTS
+	Optical Control Electronics	: OCE
@	Oscillator	: OSC
@	RF Circulator Switch	: RFCS
@	RF Switch	: RFS
@	RF Transfer Switch	: RFTS
*	Solar Array	: SA
@	Two-Axis Gimbal of HGA	: TAG

The following equipment are presently designated as HST non-ORU spares (contingency servicing) but do not statistically require servicing during a 15 year mission.

@	Coarse Sun Sensor	: CSS
@	High Gain Antenna	: HGA
@	Interface Power Control Unit	: IPCU
@	Rotary Drive Assembly	: RDA
@	RF Multiplexer	: RFM
@	Umbilical Disconnect Mechanism	: UDS
	Wave Front Sensor	: WFS

Note: * denotes Block I ORU
+ indicates Block II ORU
@ denotes Block III ORU

9.2 HST ORU Physical Characteristics (Excluding Storage Containers)

ORU	Approximate Dimensions (m)	Volume (m^3)	Approximate Mass (kg)	HST Quantity/ Spares	Ref. #
ACE	0.4 x 0.3 x 0.2	0.0206	12	1/1	38,46
BAT	0.6 x 0.3 x 0.4	0.0354	65	6/8	5,6,7,23,46
CCC	0.2 x 0.2 x 0.1	0.0046	1.4	6/1	22,46
DBA	0.1 x 0.2 x 0.9	0.0167	8	2/1	6,7,46
DF224	0.6 x 0.6 x 0.5	0.136	53	1/1	6,7,41,46
DIU	0.4 x 0.4 x 0.2	0.0266	15	3/2	6,7,25,46
DMU	0.7 x 0.8 x 0.2	0.0859	42	1/1	6,7,46
ECU	0.3 x 0.2 x 0.2	0.0122	8	3/3	6,7,44,46
EP/TCE	0.4 x 0.4 x 0.2	0.0197	13	1/2	6,7,46
ESTR	0.3 x 0.3 x 0.2	0.0132	10	3/1	6,7,26,46
FGE	0.6 x 0.3 x 0.3	0.0579	24	3/2	6,7,46
FGS	1.7 x 1.2 x 0.6	1.11	220	3/1	6,7,46
FHST	0.2 x 0.2 x 0.3	0.0082	18	3/1	33,46
FOC	0.9 x 0.9 x 2.2	1.41	320	1/0	6,7,46
FOS	0.9 x 0.9 x 2.2	1.66	310	1/0	6,7,46
FP	0.1 dia x 0.2	0.0001	0.2	14/17	5,6,7,34,46
GEA	0.2 x 0.2 x 0.4	0.0096	7	2/1	46
HRS	0.9 x 0.9 x 2.2	1.79	310	1/0	6,7,46
HSP	0.9 x 0.9 x 2.2	1.79	264	1/0	6,7,46
ICU	0.4 x 0.4 x 0.2	0.027	8	1/1	20,46
LGA	0.1 dia x 0.2	0.0027	0.3	2/2	31,46
MAT	0.3 x 0.1 x 0.1	0.0098	7	2/1	6,7,13,46
MCU	0.5 x 0.3 x 0.2	0.0299	22	1/1	6,7,42,46
MSS	0.2 x 0.2 x 0.1	0.0018	1.0	2/1	33,46
MTS	0.1 x 0.1 x 2.5	0.0079	43	4/1	33,46
OCE	0.3 x 0.3 x 0.2	0.0167	8	1/2	6,7,46
OSC	0.1 x 0.1 x 0.03	0.0018	1.3	2/1	21,46
PCU	1.1 x 0.5 x 0.2	0.0845	69	1/1	30,46
PDU	0.5 x 0.3 x 0.2	0.0155	13	4/1	6,7,43,46
PSEA	0.4 x 0.2 x 0.7	0.0759	39	1/1	28,46
RFCS	.01 x .01 x .005	0.0008	0.5	1/1	32,46
RFS	0.1 x 0.1 x 0.03	0.0001	0.3	2/1	27,46
RFTS	.05 x .05 x .05	0.0002	0.3	2/1	29,46
RSU	0.3 x 0.3 x 0.2	0.0094	11	3/3	6,7,44,46
RWA	0.6 dia x 0.5	0.136	47	4/4	6,7,45,46
SA(stowed)	2.5 x 0.4 dia	0.314	140	2/2	6,7,46
(deployed)	2.5 x 12.2 x 0.4	12.2			6,7
SADE	0.4 x 0.3 x 0.2	0.0117	7	2/1	6,7,46
SAT	0.3 x 0.2 x 0.1	0.0031	3	2/1	6,7,24,46
SIC&DH	0.9 x 0.7 x 0.3	0.109	61	1/1	6,7,46
TAG	0.4 x 0.2 x 0.2	0.015	10	2/1	33,46
WF/PC	2.1 x 0.8 x 2.0	0.795	260	1/1	6,7,46

9.3 HST ORU Storage Requirements

ORU	Survival *** Temperature Range (°C)	Operational Temperature Range (°C)	Storage Power** (watts)	Operational Power (watts)	Ref. #
ACE	TBD	TBD	TBD	TBD	
BAT	-17 to +27	-7 to +15	1.6	10	1,6,7,23
CCC	+10 to +32	TBD	3.5	TBD	22
DBA	-55 to +45	-55 to +45		42	6,7
DF224	-17 to +49	-17 to +49	125	125	1,6,7,41
DIU	-40 to +60	-40 to +60	9	24	1,6,7,25
DMU	-60 to +60	-40 to +35	25	97	1,6,7
ECU	-24 to +60	-24 to +60	18	TBD	1,6,7,44
EP/TCE	-40 to +35	-23 to +35	TBD	11	6,7
ESTR	-40 to +43	-12 to +43	0	20	1,6,7,26
FGE	-54 to +35	-23 to +35	TBD	140	6,7
FGS	+10 to +32	+21 +/ -1	88 *	140	6,7,16
FHST	TBD	TBD	TBD	14	
FOC	-10 to +35	+15 to +19	65 *	150	6,7,14
FOS	-50 to +40	-15 to +40	65 *	135	6,7,17
FP	-40 to +71	-29 to +60	0	0	
GEA	TBD	TBD	0	TBD	1
HRS	-40 to +40	+17 to +25	65 *	150	6,7,18
HSP	-35 to +35	-35 to +35	65 *	135	6,7,19
ICU	+10 to +35	TBD	7	7	1,20
LGA	+10 to +32	TBD	TBD	TBD	31
MAT	-50 to +55	-10 to +55	20	TBD	1,6,7,13
MCU	-60 to +50	-29 to +50	10	10	1,6,7,42
MSS	TBD	TBD	TBD	1.4	9
MTS	TBD	TBD	TBD	3	9
OCE	-40 to +35	-23 to +35		0	6,7
OSC	+10 to +35	TBD	2	TBD	1,21
PCU	+10 to +35	TBD	TBD	25	30
PDU	-40 to +71	-29 to +60	15	5	1,6,7,43
PSEA	+10 to +35	TBD	25	24	1,28
RFCS	+10 to +35	TBD	1.6	TBD	1,32
RFS	+10 to +32	TBD	0	TBD	1,27
RFTS	+10 to +32	TBD	0	TBD	1,29
RSU	+4 to +60	+4 to +60	TBD	47	6,7,44
RWA	-17 to +49	-17 to +49	TBD	105	6,7,45
SA	-37 to +20	-37 to +20	32	0	3.6,7
SADE	-34 to +60	-34 to +60	TBD	13	6,7
SAT	-17 to +49	-17 to +49	0	7	1,6,7
SIC&DH	-50 to +60	-25 to +30	45	99	3,6,7
TAG	TBD	TBD	TBD	TBD	
WF/PC	-50 to +32	-20 to +20	92 *	130	6,7,15

NOTES: * These values represent steady-state storage power requirements while the ORU is enclosed in the SIPE (Science Instrument Protective Enclosure).

** These numbers are based on Orbiter on-board storage/service. It is assumed that all servicing materials are brought to the Space Station by the Orbiter and are then stored in the SS servicing facility. Due to the scarcity of precise information describing the SS Storage Facility environment, it is assumed that the thermal characteristics of this facility are equivalent to the thermal characteristics of the Orbiter bay. Only in this case are these numbers significant to the SS. Otherwise, these numbers can be used for reference purposes.

*** Data includes both survival and storage temperatures. For a given ORU, if both types of temperatures were available, then only survival temperatures were chosen for presentation in this table.

9.4 Other Environmental Requirements for HST ORUs (*See NOTES below)

ORU	Surface/Environ. Contamination (Max.15 ppm hydrocarbon)	Relative Humidity	Acceleration Design Limit	ESD Sensitive	Ref. #
ACE	TBD	TBD	TBD	TBD	
BAT	500B/100K	TBD	8.8grms, 14g a.a	Yes	6,7,23
CCC	TBD	0-50%	TBD	Yes	22
DBA	500B/100K	TBD	23.3grms, 22g a.a.	TBD	6,7
DF224	500B/100K	0-50%	6.2grms, 14g a.a	Yes	6,7,41
DIU	500B/100K	10-80%	(17,12)grms, 18g a.a	Yes	6,7,25
DMU	500B/100K	TBD	[17,12]grms, 14g a.a	TBD	6,7
ECU	500B/100K	0-50%	6.2grms, 23g a.a	TBD	6,7,44
EP/TCE	500B/100K	TBD	17grms, 19g a.a	TBD	6,7
ESTR	500B/100K	10-80%	6.2grms, 22g a.a	TBD	6,7,26
FGE	500B/100K	TBD	17grms, 15g a.a	TBD	6,7
FGS	400B/10K	TBD	3.3grms, 1.86gV1, 1.76gV2, 3.86gV3	TBD	6,7
FHST	TBD	TBD	TBD	TBD	
FOC	400B/10K	TBD	4.6grms, 1.5gV1, 0.86gV2, 2.6gV3 on landing (6 fps)	TBD	6,7
FOS	400B/10K	TBD	4.6grms, 1.5gV1, 0.86gV2, 2.6gV3 on landing (6 fps)	TBD	6,7
FP	500B/100K	TBD	17grms, 18g a.a,	No	6,7,34
GEA	TBD	TBD	TBD	TBD	
HRS	400B/10K	TBD	4.6grms, 1.5gV1, 0.86gV2, 2.6gV3, on landing (6 fps)	TBD	6,7
HSP	400B/10K	TBD	4.6 grms 1.5gV1, 0.86gV2, 2.6gV3 on landing (6 fps)	Yes	6,7
ICU	500B/100K	0-50%	TBD	Yes	20
LGA	500B/100K	0-50%	TBD	TBD	31
MAT	500B/100K	0-50%	17grms, 22g a.a.	TBD	6,7,13
MCU	500B/100K	0-50%	6.2grms, 18g a.a	Yes	6,7,42
MSS	TBD	TBD	TBD	TBD	
MTS	TBD	TBD	TBD	TBD	
OCE	500B/100K	TBD	17grms, 22g a.a	TBD	6,7
OSC	500B/100K	10-50%	TBD	Yes	21
PCU	500B/100K	10-80%	TBD	Yes	30
PDU	500B/100K	0-50%	17grms, 19g a.a	No	6,7,43
PSEA	500B/100K	0-50%	TBD	Yes	28

ORU	Surface/Environ. Contamination. (Max.15 ppm hydrocarbon)	Relative Humidity	Acceleration Design Limit	ESD Sensitive	Ref. #
RFCS	500B/100K	10-80%	TBD	TBD	32
RFS	500B/100K	10-80%	TBD	TBD	27
RFTS	500B/100K	10-80%	TBD	TBD	29
RSU	400B/10K	TBD	7.1grms, 21g a,a	TBD	6,7,44
RWA	500B/100K	0-50%	6.2grms, 18g a.a	TBD	6,7,45
SA	500B/100K	TBD	8.5grms, 2gV1, 3.5gV2, 8.9gV3 in landing (6fps)	TBD	6,7 6,7
SADE	500B/100K	TBD	17grms, 22g a.a	TBD	6,7
SAT	500B/100K	0-50%	17grms, 22g a.a		6,7,24
TAG(of HGA)		TBD	TBD	TBD	
WF/PC	400B/10K	TBD	2.8grms, 3.6gV1, .77gV2, 3.19gV3 on landing (6 fps)	TBD	6,7

* NOTES:

a.a. = "any axis"
(#1,#2) = #1 parallel to base/tray,
#2 perpendicular to base/tray
[#1,#2] = #1 radial,
#2 transverse
V1, V2, V3 correspond to HST axes

10.0 HST FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 HST Flight Support Equipment (FSE)

a. Protective Covers:

- Wide Field/Planetary Camera Mirror Cover.
- ORU Electrical Connector Covers.
- Fixed-Head Star Tracker Delta Plate Cover.
- Fixed-Head Star Tracker Lightshade Cover.
- Fine Guidance Sensor Mirror Cover.

b. Flight Support System Maintenance Platform Space Station Equivalent

When serviced, the Orbiter flight support system (see Figure HST-5) maintenance platform, a U-shaped cradle, facilitates HST servicing with a rotational, pivotable berthing ring. The FSS provides power to the HST via an umbilical. The SS must have an Orbiter equivalent FSS available for servicing HST. It is assumed that the SS provides this 1900 kg, 17.6 cubic meter platform. [39,49]

c. EVA Tools [35,36]

Mechanical fasteners and associated tools are English-unit based. [39,49]

d. EVA Tool Box

Holds HST's EVA tools

e. Electrical Cabling

f. Foot Restraints

g. Umbilical Disconnect Mechanism

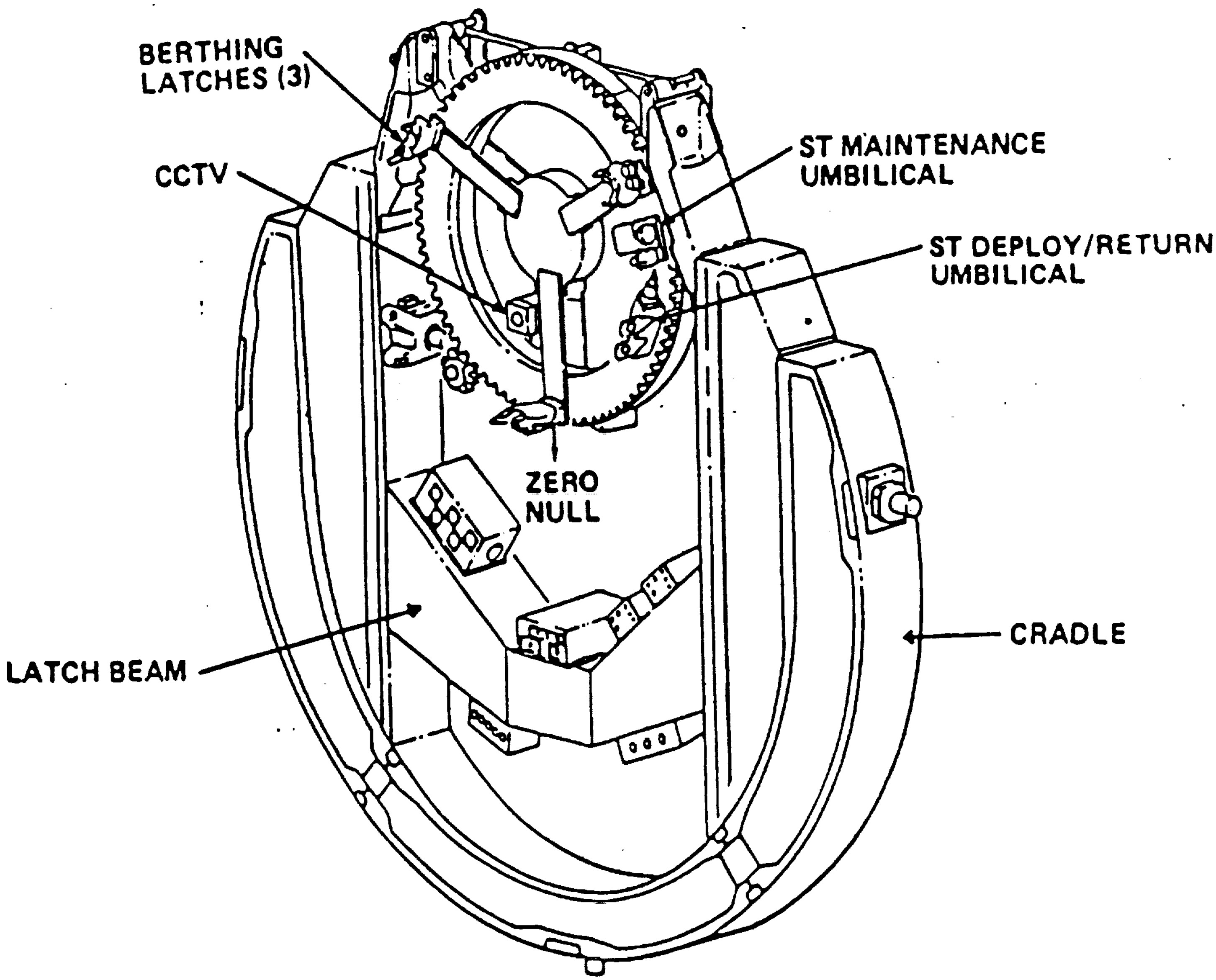

Figure HST-5. Orbiter Flight Support System (FSS) Cradle (39)

10.2 HST FSE Physical Characteristics

FSE	Quantity	Mass (kg)	Volume (m^3)	Ref. #
FGS Mirror Cover	1	3.6	0.01	50
FHST Lightshade Cover	1	0.1	0.02	50
FHST Delta Plate Cover	1	0.7	0.01	50
WF/PC Mirror Cover	1	TBD	TBD	
ORU Electric Connector Cover	28^	TBD	TBD	
HST EVA Tool Box	1	45	0.47	33
Electrical Cabling	-	10	TBD	33
Foot Restraint	2	20	0.16	33
Umbilical Disconnect Mechanism	1	12	0.06	33

10.3 HST FSE Storage Requirements

Storage requirements for FSE are not specified. However, operational FSS information indicates that the Orbiter FSS requires approximately 900 watts (28 V DC) pre- and post-dock (operational power is for reference only). [9]•

10.4 Miscellaneous Servicing Equipment

None required.

11.0 HST SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

HST is a free-flyer which requires no consumables with its current design. Future replacement IR SIs will, however, require cryogens.

11.2 Physical Characteristics

No consumables are required with HST's present configuration.

11.3 Storage Requirements

Not applicable.

12.0 CARRIERS FOR HST SERVICING MATERIALS

12.1 Description of Carrier

- ORU Carrier (ORUC)
  The ORUC (Orbital Replaceable Unit Carrier) (see Figure HST-6) is a Spacelab pallet modified with shelves and provisions for replacement parts. The ORUC transports 6 batteries every mission. The remaining shelf capacity can carry 4 to 6 small ORUs and typically 1 to 2 large ORUs (WF/PC and/or FGS, SA, axial SIs). The typical maintenance burden is forseen as: 6 batteries, 8-10 small ORUs and 1-2 large ORUs. Thus a potential shortfall in capacity, even though not an established fact, is potentially a concern. [38]
- The ORUC has a mass of 620 kg and overall dimensions of: 3.4 m long x 4.8 m wide x 4.0 m high. ORUC volume is 66 cubic meters. [39, 48]. This carrier was designed to facilitate STS-based servicing emphasizing accessibility of the ORUs. This data book assumes that this carrier will also be used in SS-based HST servicing.

12.2 STS and SS Carrier Interfaces

The loaded ORUC requires 680 W (28 V DC) to maintain ORU temperatures (in the Orbiter environment). [9]

12.3 Servicing Materials/Carrier Interfaces

HST ORUs required during servicing must be detached from the ORUC after assuring that the time required for transport and installation does not allow the ORU to reach an unacceptable temperature. Proper handling procedures (including special precautions for ESD sensitive items) must be observed.

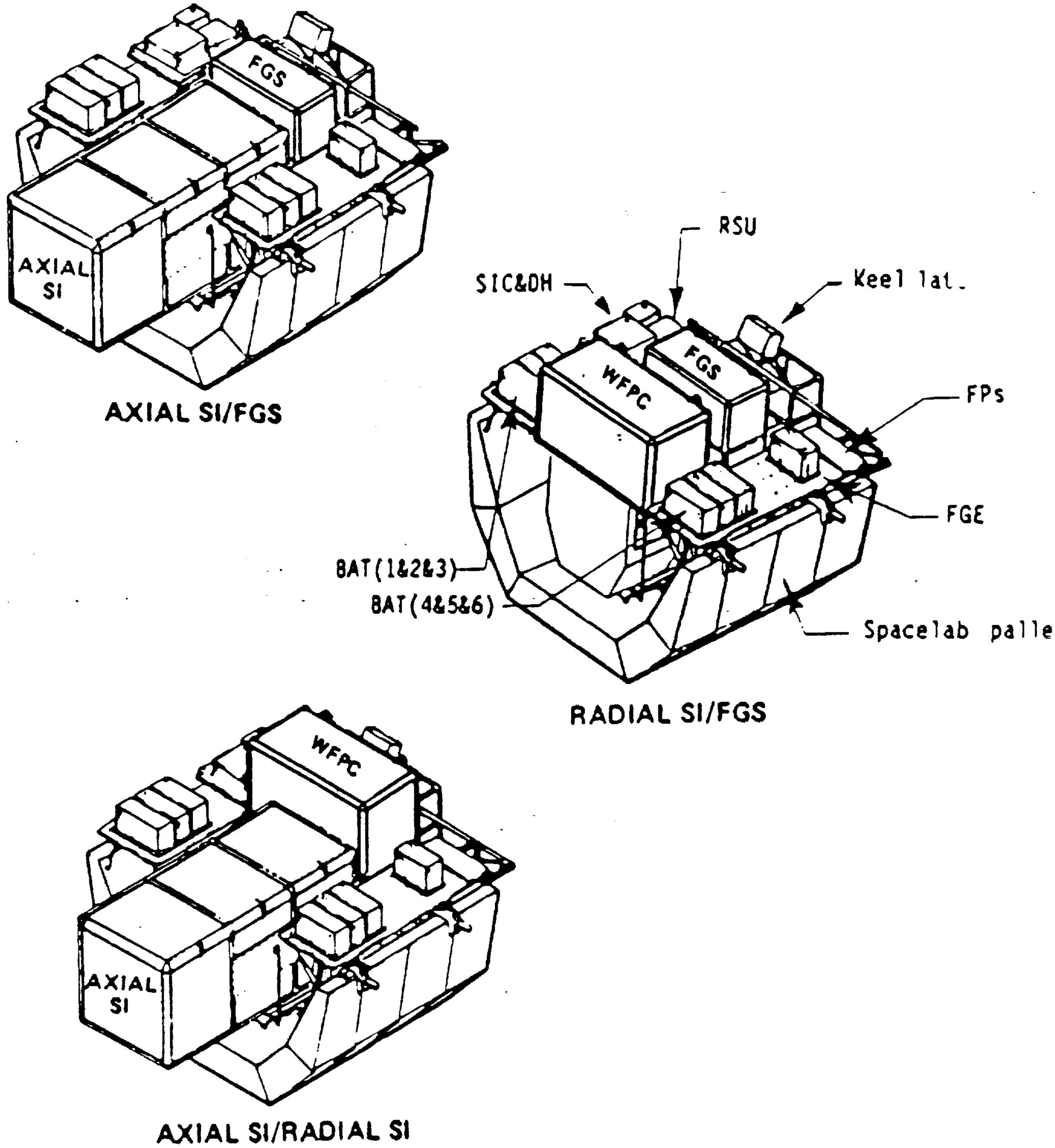

Figure HST-6. Loaded ORU Carrier Configuration (39)

13.0 HST ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 HST Mission Servicing Ground Rules and Constraints

a. Assumptions

The strawman servicing mission is described in section 14.1. Further assumptions follow:

- Grapple of HST, berthing of HST onto FSS-equivalent, connection of umbilical, and deployment sequence are all considered to be nominal as per the overall timeline. No contingencies are addressed. [5]
- During HST EVA operations the EVA timelines were designed such that crew member EV1 carries a ratchet wrench, 6-in. extension and portable foot restraint, translates with these tools to set up his workstation, and performs ORU changeouts from the installed portable foot restraints in a predetermined foot restraint receptacle. EV1 is the prime crewmember that removes the degraded ORU and installs the replacement ORU. EV2 is the crewmember who performs EVA tasks from the RMS/MFR and assists EV1 as required and unstows/stows ORUs from the carrier and transfers these components to and from the HST and ORU carrier in the RMS/MFR. [5]
- The distance between HST and the ORUC at the SS is the same as that at the Orbiter.
- During EVA operations, EV1 and EV2 are communicating as needed with IV crew to inform of EVA task status in order to minimize deactivation/activation times. In addition, communication occurs for RMS/MFR positioning and EMU suit status reports. [5]
- Lighting for EVA tasks is accomplished by use of the crewmember helmet-mounted lights, portable lights and SS service facility lights. Use of SS service facility lights will have to be determined when a more concrete timeline is established. [5]

- Changeout of batteries is completed 3-at-a-time to maximize EVA time utilization. [5]
- Thermal environments for the ORUC and the HST when serviced at the SS are assumed to be equivalent to those encountered on the Orbiter.

b. Constraints

The following constraints were identified and implemented into EVA operations when possible to minimize thermal and electrical impacts to the HST, as well as for safety reasons. [5] Additional safety constraints are listed in Section 3.6 and 4.0.

- HST power ON/OFF control: Power to most individual HST units is controlled by ground control or the SS IVA crewmember.
- Total HST power OFF periods shall be minimized. (Note: ECU and fuse plugs require main "bus" off for replacement.) [5]
- The ECU should be changed out before the RSU to avoid having to turn off the replacement RSU for ECU changeout. [5]
- Both the RGA (RSU and ECU) and the FPs require the entire HST electrical bus to be turned off to remove power to the ORU. Some SIs may require preheating before this power off mode. [47]
- If the PDU fuse plugs and the EP/TCE fuse plugs are both to be changed out in the same maintenance mission, then these two tasks and timelines should be combined and changed out together to substantially reduce the total changeout time. [5]

- The DF-224 computer should be replaced first in order to provide operating capability to other ORUs. [5]
- When both the SIC&DH and any SI must be replaced, then the SIC&DH should be replaced first. [5]
- The electronic control unit (ECU) should be replaced before the fine guidance sensor unit to minimize main bus off time and to allow the RSU heaters to be powered up on replacement of the RSU. [5,47]
- Batteries should be replaced last to minimize the depth of discharge due to drain from HST voltage monitor circuitry prior to redeployment; however, this constraint shall not override the planning for optimal sequence. [5]
- RWAs must be completely spun down to a complete stop before any EVA changeout can take place. [5]
- There may be occasions in which HST must be supported by only 2 of the 3 trunnion and keel fittings in order to leave the service area clear. [47]

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unload Servicing Materials from Orbiter	0:30^	0:30^	0:00^	0:30^
2. Berth HST to FSS	3:00 [5]	3:00	3:00^	3:00

13.3 Principal Servicing Time Estimates

ORU Replaced	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)	Ref.#
ACE	0:38^	0:38^	1:15^	0:19^	*
BAT(1&2&3)	1:20	1:20	2:40	0:40^	5
BAT(4&5&6)	1:15	1:15	2:30	0:38^	5
CCC	0:33^	0:33^	1:07^	0:16^	*
DBA	0:50	0:50	1:40	0:25^	5
DF224	0:55	0:55	1:50	0:28^	5
DIU	0:39^	0:39^	1:18^	0:20^	*
DMU	0:49^	0:49^	1:20^	0:25^	*
ECU	0:45	0:45	1:30	0:22^	5
EP/TCE	0:40	0:40	1:20	0:20^	
ESTR	0:37^	0:37^	1:14^	0:18^	*
FGS	1:30	1:30	3:00	0:45^	5
FGE	0:50	0:50	1:40	0:25^	5
FHST	0:40^	0:40^	1:20^	0:20^	*
FOC	2:29	2:29	4:58	1:15^	5
FOS	2:29	2:29	4:58	1:15^	5
FP					
FPs of EP/TCE	0:40	0:40	1:20	0:20^	5
FPs of PDU	0:50	0:50	1:40	0:25^	5
GEA	0:36^	0:36^	1:11^	0:18^	*
HRS	2:29	2:29	4:58	1:15^	5
HSP	2:29	2:29	4:58	1:15^	5
ICU	0:36^	0:36^	1:12^	0:18^	*
LGA	0:33^	0:33^	1:06^	0:16^	*
MAT	0:36^	0:36^	1:11^	0:18^	*
MCU	0:42^	0:42^	1:23^	0:21^	*
MSS	0:33^	0:33^	1:07^	0:16^	*
MTS	0:50^	0:50^	1:40^	0:25^	*
OCE	0:36^	0:36^	1:12^	0:18^	*
OSC	0:34^	0:34^	1:07^	0:17^	*
PCU	1:00^	1:00^	2:00^	0:30^	*
PDU	1:22^	1:22^	2:45^	0:41^	*
PSEA	0:48^	0:48^	1:36^	0:24^	*
RFCS	0:33^	0:33^	1:06^	0:16^	*
RFS	0:33^	0:33^	1:06^	0:16^	*
RFTS	0:33^	0:33^	1:06^	0:16^	*
RSU	1:05	1:05	2:10	0:32^	2,5
RWA	0:50	0:50	1:40	0:25^	5
SA	1:50	1:50	3:40	0:55^	5
SA&DBA	2:15	2:15	4:30	1:08^	5
SADE	0:36^	0:36^	1:11^	0:18^	*
SAT	0:34^	0:34^	1:08^	0:17^	*
SIC/DH	0:55	0:55	1:50	0:28^	5
TAG	0:37^	0:37^	1:14^	0:18^	*
WF/PC	1:40	1:40	3:20	0:50^	5

*Time estimates are based on the least-squares-error curve fit of HST ORU replacement time data from Reference [5]. T=33+0.39M T=IVA time in minutes and M=mass of ORU in kilograms. EVA time is assumed to be twice IVA time (2 EVA astronauts to 1 IVA). Robotics time is assumed to be one half of the elapsed time.

13.4 Close-Out Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Deberth HST from FSS	4:30 [5]	4:30	3:00^	4:30
2. Load Orbiter	0:30^	0:30^	0:00	0:30^

14.0 HST STRAWMAN SERVICING SCENARIO

14.1 HST Strawman Servicing Mission

The following strawman servicing mission information is derived from both MSFC and JSC data and neutral bouyancy tank tests at MSFC. The mission reflects 14 hours of EVA activity. This strawman, Strawman A, represents the first SS servicing mission, utilizing 3 crew members including 2 EVA astronauts, 9 years after HST deployment. It entails the changeout of 9 types of ORUs and one SI. Approximately 12 hours of elapsed time during EV servicing activities are required to changeout only those components which need to be replaced every three years. Information for this strawman mission is derived from data published relating to maintenance at the Orbiter.

Prior to HST EVA operations, the HST is positioned on the FSS-equivalent and latched securely. The RMS is also powered up and checked out for grapple of MFR.

EV1 (denoting EVA astronaut number 1) utilizes a 6-inch extension and portable foot restraint to perform ORU changeout. EV2 uses the RMS/MFR and assists EV1 by unstowing/stowing/transferring ORUs. Lighting is accomplished with helmet lights, portable lights, and cargo bay lights.

14.2 HST Description

During servicing, the Space Station must accommodate HST's physical characteristics:

- Mass: 11600 kg
- Envelope Dimensions:
  - Deployed: 16.1 m long x 12.3 m x 12.6 m
  - Stowed: 13.1 m long x 4.3 m dia
- Volume:
  - Deployed: 2500 cubic meters
  - Stowed: 190 cubic meters

14.3 Strawman Servicing Materials

a. ORUs

The following components will be replaced during this mission:

ORU	Quantity	Dimensions (m)	Volume (m^3)	Mass (kg)	Storage Power (W)
BAT	6	0.6 x 0.3 x 0.4	0.0354	65	1.6
DF224	1	0.6 x 0.6 x 0.5	0.136	53	125
DIU	3	0.4 x 0.4 x 0.2	0.0266	15	9
ECU	1	0.3 x 0.3 x 0.2	0.0122	8	18
ESTR	3	0.3 x 0.3 x 0.2	0.0132	10	0
FGE	1	0.6 x 0.6 x 0.3	0.0579	24	TBD
FGS	1	1.7 x 1.2 x 0.6	1.11	220	88
RSU	3	0.3 x 0.3 x 0.2	0.0094	11	TBD
SIC&DH	1	0.9 x 0.7 x 0.3	0.109	61	45
WF/PC	1	2.1 x 0.8 x 2.0	0.795	260	92
Total	21	-	2.58	1125	-

b. FSE and Miscellaneous Equipment

The following FSE items will be used during the service mission:

FSE	Quantity	Mass (kg)	Storage Power (W)
FGS Mirror Cover	1	3.6	0.01
FHST Lightshade Cover	1	0.1	0.02
FHST Delta Plate Cover	1	0.7	0.01
WF/PC Mirror Cover	1	3.0^	0.01^
ORU Electric Connector Cover	20^	0.1^	0.01^
EVA Tool Box	1	45	0.47
Electrical Cabling	1	10	0.02^
Foot Restraint	2	20	0.16
Umbilical Disconnect Mechanism	1^	12	0.06
Total	29	120	1.12

c. Consumables and Containers

Not applicable.

d. Carriers

The ORU carrier (1 required) has a mass of 620 kg and a volume of 66 cubic meters.

14.4 Estimated STS Up/Down Mass to Support HST Strawman Servicing

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	260	0	260
ORU(s)	865	0	865
Unique FSE	120	0	120
Misc. Equipment	0	0	0
Equipment Subtotal	1245	0	1245
Equipment Carrier(s)	620	0	620
Subtotal, Equipment Mass Up	1865	0	1865
Subtotal, Equipment Mass Down	1865	0	1865

Consumables

Consumables	0	0	0
Consumables, Containers	0	0	0
Consumables Containers Carriers	0	0	0
Subtotal, Consumables Mass Up	0	0	0
Subtotal, Consumables Mass Down	0	0	0
Total Mass Up	1865	0	1865
Total Mass Down	1865	0	1865

14.5 Estimated STS Up/Down Volume to Support HST Strawman Servicing

SERVICING MATERIAL	VOLUME UNPRESSURIZED TRANSPORT (m^3)	VOLUME PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	0.80	0	0.8
ORU(s)	1.78	0	1.78
Unique FSE	1.1	0	1.1
Misc. Equipment	0.0	0	0.0
Equipment Subtotal	3.7	0	3.7
Equipment and Carriers Subtotal	66	0	66
Consumables			
Consumables in Containers	0	0	0
Consumables, Containers and Carriers	0	0	0
Total Volume Up	66	0	66
Total Volume Down	66	0	66

14.6 Storage on Space Station Required to Support Strawman HST Servicing

Continuous Storage*	Unpressurized	Pressurized	Total
Mass (kg)	0	0	0
Volume (m^3)	0	0	0
Average Power (watts)	0	0	0
Temperature Range (°C)	-	-	-
Temporary Storage			
Mass (kg)	1865	0	1865
Volume (m^3)	66	0	66
Average Power (watts)	680	0	680
Temperature Range (°C)	10 to +27	0	+10 to +27

*It is assumed that the FSS (the GSFC A' Cradle) is not chargeable to HST as this platform (or its SS-equivalent) is standard SS equipment used by other spacecraft.

14.7 HST Strawman Servicing Power Estimate

	Operational Mode AVG	Operational Mode MAX	Servicing Mode AVG	Servicing Mode MAX
HST (Bus + Instruments)	2100 W	TBD	1700 W	2700 W*

*For 7 minutes during servicing

14.8 HST Strawman Servicing Times*

Activity	Elapsed Time (hr:min)	IVA Time Crew-hr:min)	EVA Time Crew-hr:min)	Robotics Time (hr:min)
1. Unload Servicing Materials from Orbiter	0:30^	0:30^	0:00^	0:30^
2. Berth HST to FSS	3:00	3:00	3:00^	3:00
3. ORUs Replaced: (Number of Units)				
(1) DF-224 Computer	0:55	0:55	1:50	0:28^
(1) SIC&DH	0:55	0:55	1:50	0:28^
(1) ECU	0:45	0:45	1:30	0:22^
(3) ESTR's	0:45^	0:45^	1:29^	0:22^
(3) RSU's	3:15	3:15	6:30	1:38'
(1) FGS	1:30	1:30	3:15	0:45^
(1) FGE	0:50	0:50	1:40	0:25^
(6) BAT (1 thru 6)	2:35	2:35	5:10	1:18^
(3) DIU's	0:51^	0:51^	1:41^	0:26^
(1) WF/PC	1:40	1:40	3:20	0:50^
4. Load Orbiter with servicing materials	0:30^	0:30^	0:00^	0:30^
5. Deberth HST	4:30	4:30	3:00^	4:30
Total	22:30^	22:30^	34:15^	15:30^

* BDM time estimates are based on the least-squares-error curve fit of HST ORU replacement time data from Reference [5]. T=33+.39M when T=IVA time in minutes and M=Mass to be replaced in kilograms. EVA time is assumed to be twice IVA time. Robotics time is estimated at one half of elapsed time.

14.9 OMV Flights in Support of HST Strawman Servicing Mission

Strawman Mission	Purpose of Flight	Number of Flights
Strawman A	Retrieval	1
Strawman B	Redeployment	1

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF HST

15.1 HST Milestone and Servicing Schedule (Nominal Mission Model)

Event	Location	Date
HST Launch	KSC	3rd quarter, 1989
1st Servicing	STS	3rd quarter, 1992
2nd Servicing	STS	3rd quarter, 1995
3rd Servicing	SS	3rd quarter, 1998
4th Servicing	SS	2nd quarter, 2000
5th Servicing	SS	1st quarter, 2002
HST Mission Termination		4th quarter, 2003

15.2 Summary of HST Mass Considerations

a. HST Mass (Operational HST and HST During Servicing)

Oper HST Mass (dry):	11600 kg	Servicing HST Mass (dry):	11600 kg
Oper Consumables Mass:	0 kg	Servicing Consumables Mass:	0 kg
Oper HST Mass (total)	11600 kg	Servicing HST Mass:	11600 kg

b. HST Servicing Mass Up and Down in STS*

Event	Mass Up (kg)	Mass Down (kg)
Launch	13500	1900
1st Servicing	3765	3765
2nd Servicing	3765	3765
3rd Servicing	1865	1865
4th Servicing	1865	1865
5th Servicing	1865	1865
HST Mission Termination	1900	13500
Totals	28525	28525
SS Servicing Totals	5600	5600

c. HST Servicing Storage Mass on Space Station

Calendar Year	96	97	98	99	00	01	02	03	04	05
Storage Mass (kg)										
Unpressurized	0	0	1865	0	1865	0	1865	*	0	0
Pressurized	0	0	0	0	0	0	0	0	0	0
Total	0	0	1865	0	1865	0	1865	*	0	0

* Mission Termination during 4th quarter.

15.3 Summary of HST Volume Considerations

a. HST Volume

HST Volume, Operational Configuration: 2500 m^3
HST Volume, Servicing Configuration: 2500 m^3
HST Volume, Storage/Transportation Configuration: 190 m^3

b. HST Servicing Volumes Up and Down in STS

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	190	18
1st Servicing (STS)	84	84
2nd Servicing (STS)	84	84
3rd Servicing (SS)	66	66
4th Servicing (SS)	66	66
5th Servicing (SS)	66	66
HST Mission Termination	18	208
Totals	590	590
SS Servicing Totals**	200	200

c. HST Servicing Storage Volume on Space Station

Calendar Year	96	97	98	99	00	01	02	03	04	05
Storage Mass (kg)										
Unpressurized	0	0	66	0	66	0	66	*	0	0
Pressurized	0	0	0	0	0	0	0	0	0	0
Total	0	0	66	0	66	0	66	*	0	0

* Mission termination during 4th quarter.

15.4 Summary of HST Power Considerations

	AVG	MAX
HST Operational Power (watts)	2100	TBD
HST Servicing Power (watts)	1700	2700
Storage Power, Servicing Materials (watts)	680	N.A.

15.5 Summary of HST Servicing Time

Calendar Year	97	98	99	00	01	02	03	04	Total
Elapsed Time (hr:min)	0:00	22:30^	0:00	22:30^	0:00	22:30^	0:00*	0:00	67:30
IVA Time (Crew-hr:min)	0:00	22:30^	0:00	22:30^	0:00	22:30^	0:00*	0:00	67:30
EVA Time (Crew-hr:min)	0:00	34:15^	0:00	34:15^	0:00	34:15^	0:00*	0:00	102:75
Total Crew Time (hr:min)	0:00	56:45^	0:00	56:45^	0:00	56:45^	0:00*	0:00	170:15
Robotics Time (hr:min)	0:00	15:30^	0:00	15:30^	0:00	15:30^	0:00*	0:00	46:30

*Mission termination during 4th quarter

15.6 Summary of OMV Flights in Support of HST Servicing

Calendar Year	97	98	99	00	01	02	03	04	TOTAL
Number of OMV Flights	0	2*	0	2*	0	2*	1**	0	7

* retrieval and deployment
** retrieval

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LARGE AREA MODULAR ARRAY OF REFLECTORS (LAMAR): MISSION CODE TBD

1.0 LAMAR PROGRAM AND OPERATIONS INFORMATION

1.1 LAMAR Points of Contact

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1.2 LAMAR Objectives

The objective of this experiment is to perform sensitive cosmic X-ray observations in the energy range of 0.10 to 10 keV as an attached payload of the Space Station. These observations may be categorized as follows:

(1) Study of Clusters of Galaxies, Spatially Resolved Structure and Temperature Measurements.

(2) Time Variations in an X-ray Photometry Study of Pre-Main Sequence Stellar Associations.

(3) High Resolution Spectroscopy of Cosmic X-ray Sources

1.3 LAMAR Milestone and Servicing Schedule

- Launch Date: TBD
- First Space Station Service: Launch Date + 3 years.
- Servicing Interval: 3 years.
- Operational Lifetime: TBD

This data views LAMAR as an attached payload. If LAMAR is mounted instead on the Shuttle High Energy Astrophysic Laboratory (SHEAL) Two Axis Pointing System (TAPS), the First Service date will change to Launch Date + 1 year.

1.4 LAMAR Orbital Parameters

The LAMAR instrument is an attached payload of the Space Station, which dictates the orbital parameters of the instrument. The design of the LAMAR interface mount will dictate the degree of pointing control available for viewing. The following are preferred orbital parameters for LAMAR.

- Celestial Viewing - Three axis stabilized pointings at selected targets

  Pointing Accuracy - 3 arc minutes

  Pointing Stability - 10 arc seconds per second

  Constraints - Sun avoidance of 60 degrees cone angle

  - No data within 23 degrees of Earth's limb
  - Shutdown during high background particle rate

- To meet the LAMAR celestial viewing requirements the interface mount between the instrument and the Space Station may be required to provide a combination of 180 degrees of rotation and a 90 degree hinge.

2.0 LAMAR PHYSICAL CHARACTERISTICS

2.1 LAMAR Description

Two possible configurations are under consideration for LAMAR: Option A or Option B. Option A has a maximum of thirty-two (32) Telescope and Imaging Proportional Counters mounted on a Payload Positioning System (PPS). Option B is an eight (8) Telescope and Imaging Proportional Counter Assembly mounted on the SHEAL Two Axis Pointing System (TAPS). Except as noted, the servicing information contained herein applies to Option A. The LAMAR instrument configured for Space Station operation (Option A) and mounted on the SS Payload Positioning System (PPS) is shown in Figure LAMAR-1. The Option A version of LAMAR consists of the following:

- Protective cover assemblies.

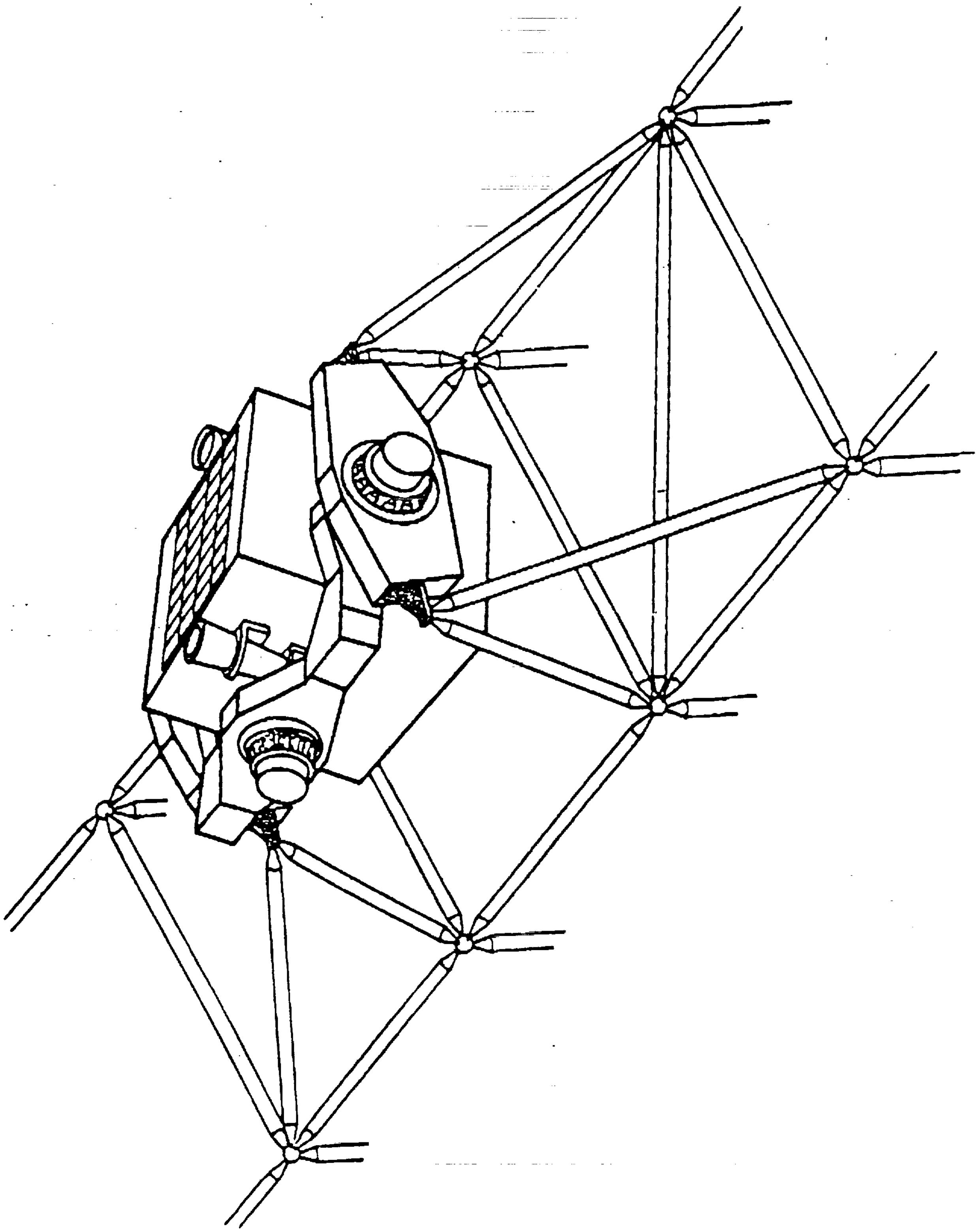

Figure LAMAR-1. LAMAR Space Station Configuration (Option A)

- Thirty-two co-aligned grazing incidence Kirkpatrick-Baez X-ray telescope assemblies with gas filled imaging proportional counters at each focus.
- Two star cameras (a prime and a backup), to provide aspect data for post-facto aspect determination used in image reconstruction.
- Two SAADs to protect the counters from high background fluxes similar to those found in the South Atlantic Anomaly.
- Two BODs to protect the Star cameras and the detectors from exposure to bright objects.
- Thermal control system to maintain passive/active thermal control independent of the Space Station.
- Command and data handling electronics.
- Main structure which provides the proper mounting interfaces for all the LAMAR instrument subsystems and shall provide the principal mounting interface between the LAMAR and the Space Station mounted Payload Pointing System.
- Gas System consisting of a gas reservoir and fill module, a gas distribution module, and a gas vent panel for the LAMAR gas (a gas mixture of 90% xenon and 10% methane).
- Flexible cabling to carry the electrical power from the Space Station to the LAMAR and a data bit stream.
- Flexible gas line to connect the LAMAR instrument with the gas reservoir and fill module if the module is mounted remotely from the LAMAR on the Space Station.

For completeness, the Option B configuration (LAMAR/SHEAL) is shown in Figure LAMAR-2. A cut-away view of this configuration is provided in Figure LAMAR-3, which also illustrates the major features of Option A. The major components of Option B are identical with those of Option A, except as follows:

- Eight Kirpatrick-Baez X-ray telescope assemblies and proportional counters instead of thirty-two (maximum).
- One star camera instead of two.
- One SAAD instead of two.
- One BOD instead of two.
- Gas system configured for servicing at one year intervals
- The main structure shall interface with the Shuttle's TAPS.

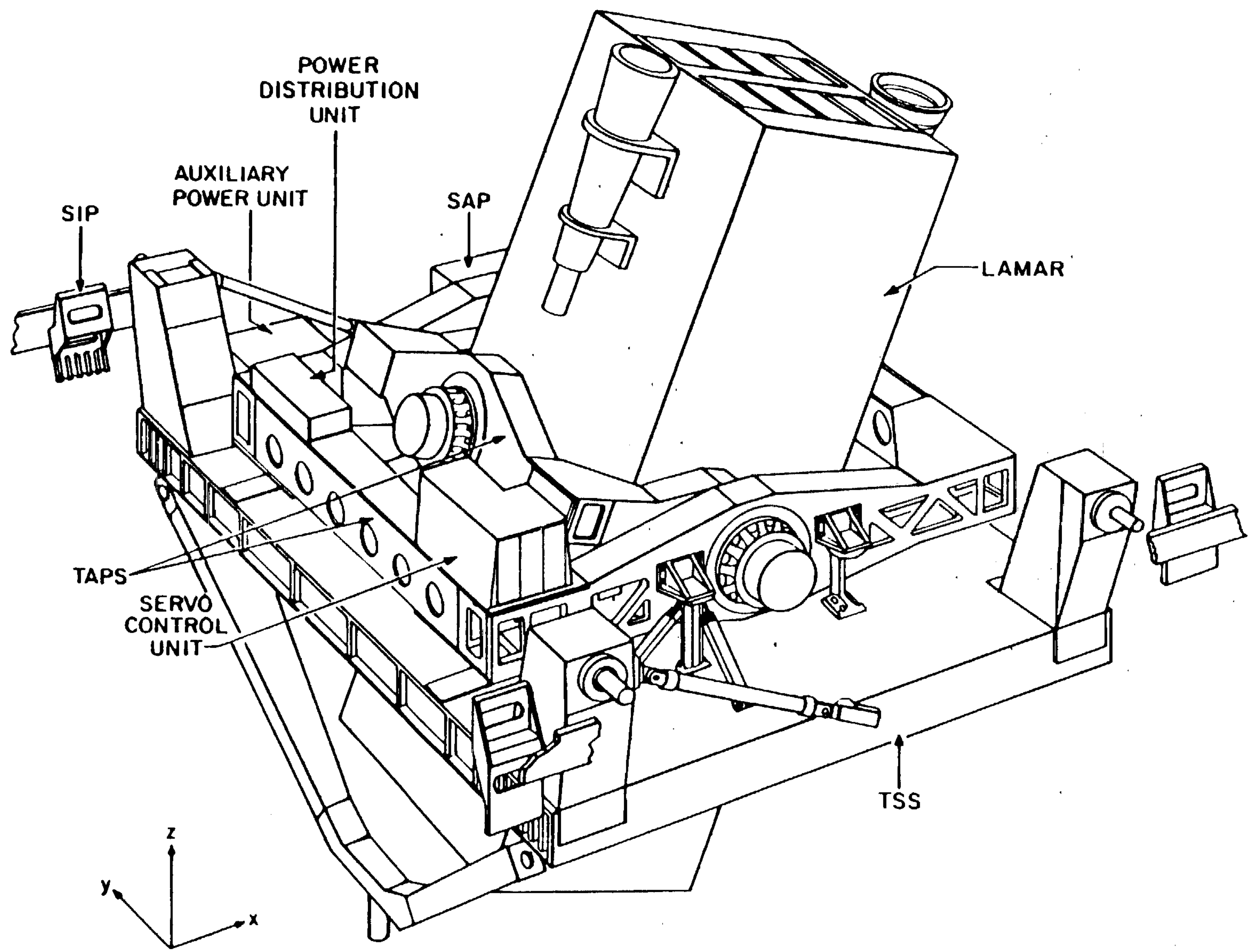

Figure LAMAR-2. LAMAR/SHEAL Payload Configuration (Option B)

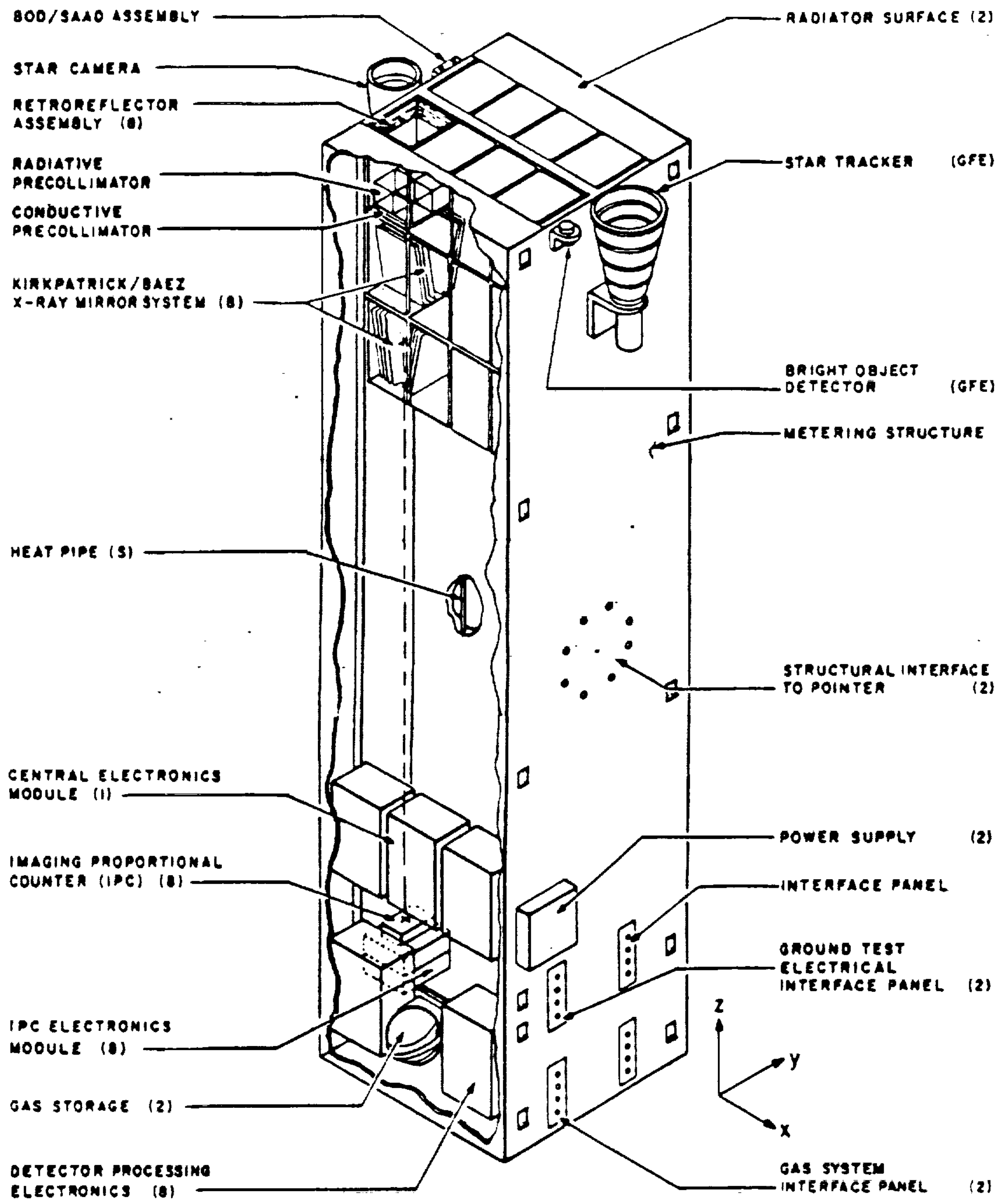

Figure LAMAR-3. LAMAR Instrument (Option B)

2.2 LAMAR Physical Characteristics

a. Mass

Dry Mass: approximately 6818 kg (15,000 lbs.)

b. Dimensions

2 x 2 x 6.3 m

(Viewing aperature is 2 m x 2 m; length = 6.3 m)

c. Envelope

2 x 2 x 6.3 m

d. Gas Reservoir

As presently envisioned, the gas reservoir and fill module of the LAMAR, holding the gas mixture in a gaseous state, is configured to mount at the rear of the instrument. As an alternate mounting for the LAMAR, this module can be removed from the instrument and mounted remotely on the Space Station, provided a flexible gas connection (containing the gas mixture at a pressure of 26 psia) is added. This will reduce the total load on the pointing system provided for LAMAR by the Space Station. The gas reservoir and fill module will measure about 2 m x 2 m x 2 m and weigh approximately 1455 kg (3200 lbs).

A second alternative is to provide gas for the LAMAR in a liquified state. This would reduce both the size and the weight of the gas reservoir and fill module, and remotely mounting this smaller module on the Space Station would also reduce the total load on the pointing system provided for LAMAR. This alternative is currently under study and no servicing data for this configuration is available.

2.3 LAMAR Moving Parts and Special Features

- Protective Cover, activated by the BOD or ground command.
- Flexible gas lines from the gas module assembly to the LAMAR.
- Flexible electrical cable for power and data signal transfer.

2.4 LAMAR Consumables

The PPS mounted LAMAR, configured for the three year mission on the Space Station, utilizes a 90% xenon, 10% methane gas mixture stored as a gas at a pressure of 850 psia in the nine (9), ~ 34 inch diameter reservoirs of the gas module assembly.

The TAPS mounted LAMAR, configured for a one year mission on the Space Station, utilizes the same gas mixture, stored at the same pressure in two (2), ~ 10 inch diameter reservoirs of the gas module assembly.

3.0 LAMAR SERVICING INFORMATION

3.1 General Description of LAMAR Servicing

Normally the LAMAR instrument will require scheduled servicing for gas replenishment at approximately three year intervals requiring the replacement of the gas reservoir and fill module. This activity will require an EVA to the PPS mounted LAMAR instrument location on the Space Station and will require the services of two suited astronauts, with proper training and tools. A Mobile Remote Manipulator System (MRMS), may also be used to transfer the gas module and carrier assembly from the Servicing Bay of the Space Station to the LAMAR. The depleted gas reservoir module will be transferred to the Servicing Bay for return to Earth in the Shuttle on an "as space available" basis.

a. Scheduled Maintenance (Replenishment of Consumables)

The on-orbit LAMAR gas replenishment activity will encompass:

- Launch of the fully pressurized (850 psia) LAMAR gas module mounted in its unpressurized shuttle payload bay carrier.
- On orbit transfer to the LAMAR gas module and carrier to the Space Station Servicing Bay for the gas replenishment preparation activities.
- Mating and checkout of the LAMAR gas module carrier and the MRMS in the Servicing Bay prior to scheduled EVA.
- Transfer of the LAMAR gas module to LAMAR mounting position on the Space Station via MRMS with control by suited astronauts.

- Decoupling of the depleted gas module on the LAMAR via flexible gas line disconnect and release of gas module holding mechanism. Transfer of the unit to carrier (astronaut activity), and restraint via tether clear of all other hardware/mechanisms.
- Removal of resupply gas module from carrier via release of gas holding mechanism and installation on LAMAR via activation of gas module holding mechanism. Attachment of the interconnect flexible gas line with the LAMAR.
- Installation of the depleted gas module into carrier, activation of the gas module holding mechanism and transfer via MRMS to the Servicing Bay of the Space Station.

b. <u>Unscheduled Servicing (not addressed in this document)</u>

Unscheduled on-orbit servicing of the LAMAR instrument may be required by the premature component failure or an Instrument upgrade. Premature component failure is defined as:

- Failure of a critical electronic assembly of a module.
- Failure of a critical component in the aspect system.
- Failure of a critical component in the protective systems. (SAAD, BOD or Protective Cover Assembly)
- Failure of a critical gas system component.

The inherent redundancy in having multiple detectors and the redundancy that will be designed into the aspect and protective systems result in a low probability for this type of servicing.

Instrument upgrade is defined as:

- Replacement of detector assemblies or detector segments.
- Replacement of electronic assemblies or segments.
- Replacement of an assembly of the aspect system.
- Replacement of an MLI blanket or protective cover.

All unscheduled servicing of the LAMAR instrument listed above with the exception of replacement of a segment of a detector or electronic assembly can be performed at the LAMAR instrument location on the Space Station. Replacement

of segments of an assembly will require the services of a properly trained astronaut in a shirtsleeve environment.

3.2 <u>LAMAR Background</u>

The LAMAR Instrument proposed for the Option B Space Station experiment is the SHEAL payload mission utilizing the Two Axis Pointing System.

The LAMAR instrument proposed as Option A is an expanded version of Option B which takes advantage of the modular nature of the design in increasing from eight (8) to a maximum of thirty-two (32) Telescopes.

The imaging Proportional Counter (IPC), of both the proposed Space Station mounted LAMAR instrument and the SHEAL TAPS mounted payload instrument utilize improved versions of the IPC successfully flown on the Einstein Observatory.

3.3 <u>Primary Role of Space Station in Servicing LAMAR</u>

The primary role of the Space Station in the servicing of the LAMAR instrument will be to provide a base of operations for the servicing activities, a pre-servicing staging area and a post-servicing storage area for the LAMAR instrument hardware.

3.4 <u>Primary Space Station Facilities Required for Servicing LAMAR</u>

Space Station facilities required for the on-orbit servicing of the LAMAR instrument are:

- Receiving and storage area (with proper tie downs), for the LAMAR instrument hardware (gas reservoir module, detector, electronic assembly or other component of the instrument, refer paragraph 3.1), and the Shuttle interface carrier.
- Provide a storage area with the proper protective, thermal and contamination controlled environment, with monitoring capabilities for the LAMAR instrument stored hardware.
- Provide a staging area for the pre-installation (EVA) checkout and visual inspection of the LAMAR instrument replacement hardware.
- Provide a storage area with the proper protective, thermal and contamination controlled environment, with monitoring capabilities for the replaced LAMAR instrument hardware.

3.5 Space Station Personnel Required for Servicing LAMAR

Space Station personnel skilled in the art of on-orbit servicing (replacement/repair), of the LAMAR instrument hardware will be required. At the module or assembly level of replacement, the instrument hardware will utilize, to the maximum extent possible, standard hardware, tools, methods and procedures employed by astronauts during previous successful missions. At the component level of refurbishment, astronauts highly trained in the specifics of handling, disassembly, installation and checkout of component parts of an assembly in a shirtsleeve environment will be required.

3.6 Servicing Precautions for LAMAR

The sensitive portions of the LAMAR instrument are:

- The telescope assemblies, located at the viewing end of the instrument, are sensitive to particle contamination.
- The thermal control radiators, located at the viewing end of the instrument, are sensitive to contamination (vernier jet discharge).
- Care in the transfer of the LAMAR instrument hardware to and from the Space Station Servicing Facility to the mounting location of the LAMAR instrument on the Space Station.
- Care in the proper alignment of connectors, fittings and couplings during the installation and removal of the LAMAR instrument hardware.
- Other instrument precautions are TBD.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support Payload

The use of an OMV is not anticipated for this Space Station attached instrument.

4.0 LAMAR SERVICING SAFETY CONSIDERATIONS

4.1 LAMAR Hazardous Systems

TBD. All safety critical systems, hazard groups and applicable safety requirements for subsystems of the LAMAR instrument for both ground and space operations will have been extensively defined prior to the Space Station mission due primarily to the experience gained in the preparations and flight of the SHEAL mission in TBD.

The LAMAR instrument will contain up to thirty-two (32) radioisotope sources with a total maximum activity of 64 millicuries (2 millicuries of Curium 244 per IPC). The aggregate of penetrating characteristic of the X radiations emitted by the payload radioactive materials will be essentially undetectable at the surface of the instrument package.

4.2 LAMAR Servicing Safety Precautions

Hazards to the crew servicing LAMAR are TBD. No major hazards (peculiar to LAMAR) are anticipated.

5.0 LAMAR SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 LAMAR Crew Convenience Features

Payload crew convenience features to accommodate a safe and expeditious on-orbit transfer and replacement will be a prime consideration in the design of LAMAR instrument component carriers and instrument hardware. Other considerations and definitions are TBD.

5.2 LAMAR Mechanical Interfaces

Since the LAMAR instrument mounts directly to the PPS or the TAPS there will be no direct mechanical interfaces between the LAMAR instrument and the Space Station. If the gas module for the LAMAR is located remotely, the gas module will have a (TBD) mechanical interface with the Space Station as will the flexible transfer gas line to the LAMAR instrument. See section 2.2 for preliminary sizes of the gas module.

The on-orbit replacement of large assemblies of the LAMAR (such as the module), may require the use of tethers for holding during an EVA.

5.3 LAMAR Umbilical Interfaces

a. Power

- 28 VDC.
- TBD kw during servicing and storage.
- TBD kw during operation.

b. Data

TBD

c. Fluid

None identified.

5.4 LAMAR RF Communication Interface

The means to transfer the command and data bit stream to and from the Space Station and a ground station will be required from the Space Station. Data rates are TBD.

5.5 LAMAR Thermal Interface

The thermal interface between the LAMAR and the Space Station is TBD at this time. However, the during contingency replacement of a component of a LAMAR assembly in a shirtsleeve environment, a thermal environment of 16-25 degrees C will be required.

6.0 LAMAR SERVICING ENVIRONMENT

6.1 LAMAR Pointing/Orientation Constraints

TBD.

6.2 LAMAR Contamination Concerns

The LAMAR will be fabricated and tested in a controlled environment which meets the Class 10000 level of Federal Standard 209B. Contamination during LAMAR launch and on-orbit servicing is to be restricted in order to eliminate degradation of the LAMAR gas, the gas module and the telescope assemblies. Contamination from the vernier pointing thrusters is of special concern.

Other contamination concerns TBD.

6.3 LAMAR Radiation Concerns

The on-board radiation sources are specified in paragraph 4.1. The sensitivity of the LAMAR instrument to external radiation, measured at the surface of the LAMAR is TBD.

7.0 LAMAR SERVICING ACCOMMODATIONS

7.1 LAMAR Equipment Access

The LAMAR design incorporates consideration for ease of access to serviceable subsystems.

7.2 LAMAR Modularity

The gas reservoir module and other ORUs described below (sections 9.1 and 9.2) are modular in nature.

7.3 LAMAR Automated Servicing

TBD

7.4 LAMAR Servicing in the Space Station Pressurized Modules

During contingency servicing at the component level of refurbishment, IVA workbench servicing in the pressurized portions of the SS is envisioned. Details are TBD.

8.0 LAMAR SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Ref.Section
ORUs (including SIs)	Yes	No	9.0
Flight Support Equipment	No	No	10.0
Other Equipment	No	No	10.0
Servicing Equipment Carrier(s)*	Yes	No	12.0
Servicing Consumables			
Propellant(s)	No	No	11.0
container(s)	No	No	11.0
Cryogen(s)	No	No	11.0
container(s)	No	No	11.0
Liquids(s)	No	No	11.0
container(s)	No	No	11.0
Gas(es)	Yes	No	11.0
container(s)	Yes	No	11.0
Other(s)	No	No	11.0
container(s)	No	No	11.0
Servicing Consumables Carrier(s)*	No	No	12.0

*Carriers for servicing materials are typically used during transportation in STS Orbiter and/or during storage on SS. A single carrier may be used.

9.0 LAMAR ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of LAMAR ORUs

a. Primary

The gas reservoir module, replaced for gas replenishment on approximately three year intervals is the only LAMAR instrument primary ORU identified at this time. Other primary ORUs are TBD.

b. Secondary

The replacement of an Imaging Proportional Counter Assembly, Electronic Assembly (Central Electronic Assembly, Detector Processing Electronics), an Aspect Sensor Assembly, MLI blanket or Protective Cover Assembly due to a premature component failure or an instrument upgrade, as indicated in section 3.1, is viewed as contingency servicing of secondary ORUs. Other ORUs are TBD.

9.2 LAMAR ORU Physical Characteristics

The gas reservoir module at launch is estimated to measure 2 m x 2 m x 2 m and weigh approximately 1455 kg (3200 lbs) (Mass for the liquified gas option is TBD.) The mass of the return gas module is about 732 kg. The weight of the gas module carrier is estimated as 950 kg for either option. Additional LAMAR ORU characteristics are shown in Table LAMAR-1.

9.3 LAMAR ORU Storage Requirements

TBD

9.4 Other Environmental Requirements for LAMAR ORUs

TBD

TABLE LAMAR-1. LAMAR ORU PHYSICAL CHARACTERISTICS

ORU NAME	MASS (kg)	DIMENSIONS (m)	NUMBER
Gas Reservoir Module	1455	2 x 2 x 2	1
Imaging Proportional Counter Assembly	13.6	.29 x .22 x .28	32
Multilayer Insulation (MLI) Blanket	TBD	TBD	1
Protective Cover Assembly	TBD	TBD	1
Detector Processing Electronics (DPE)	10.9	.13 x .23 x .30	32
Central Electronics Assembly (CEA)	15.6	.32 x .58 x .39	1
Bright Object Detector (BOD)	1.3	.10 x .10 x .18	1
South Atlantic Anomaly Detector (SAAD)	1.4	.18 x .05 x .15	1

10.0 LAMAR FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 LAMAR Flight Support Equipment (FSE)

LAMAR FSE is expected to be minimal. Little or no mission-unique tooling or cabling should be required.

10.2 LAMAR FSE Physical Characteristics

TBD

10.3 LAMAR FSE Storage Requirements

TBD

10.4 Miscellaneous Servicing Equipment

11.0 LAMAR SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

LAMAR user 90% xenon, 10% methane gas mixture stored at 850 psia for detection in the image proportional counters. Gas will be replenished approximately every three years by changeout of the gas module. Transport of the gas module requires a carrier on both the STS and the SS. See section 3.1 for additional details.

11.2 Physical Characteristics

The gas reservoir and fill module measures 2 x 2 x 2 m and weighs approximately 1455 kg (3200 lbs) at launch. The mass of the return module is 732 kg.

11.3 Storage Requirements

TBD

12.0 CARRIERS FOR LAMAR SERVICING MATERIALS

12.1 Description of Carriers

The unpressurized gas module carrier is used in the STS and on SS. It has a weight of 950 kg and a volume of TBD.

12.2 STS and SS Carrier Interfaces

Interface of the carrier with the STS is TBD. Restraint of the carrier (with gas module) via tether clear of all other hardware/mechanisms will be used on the SS. The carrier will be unloaded from the STS and transported to the LAMAR attach point for the changeout.

12.3 Servicing Material/Carrier Interfaces

The gas module is exchanged at the LAMAR instrument site. See Section 3.1 for additional details.

13.0 LAMAR ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

TBD

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unloading servicing material from STS to SS	0:30^	0:30^	0:00^	0:30^
2. Transport Servicing Material To LAMAR	1:30^	3:00^	3:00^	1:30^

13.3 Principal Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Gas Module Changeout	10:59^	16:28^	21:58^	5:30^

13.4 Closeout Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Transport servicing material from LAMAR	1:30^	3:00^	3:00^	1:30^
2. Loading of servicing material from SS to STS	0:30^	0:30^	0:00^	0:30^

14.0 LAMAR STRAWMAN SERVICING SCENARIO

14.1 LAMAR Strawman Servicing Mission

Only one strawman mission (strawman A) is defined for LAMAR. It consists of the replacement of the gas reservoir and fill module. Section 3.1 provides a detailed sequence of events.

14.2 LAMAR Description

LAMAR's servicing configuration is the same as its operational configuration (see Figure LAMAR-1). Its mass is 6818 kg, its volume 25.2 m^3, and its overall dimensions are 2 x 2 x 6.3 m.

14.3 Strawman Servicing Materials

a. ORUs

The relevant ORU (gas module) has the following properties:

Quantity	Mass (kg)	Volume (m^3)	Power (kW)
1	1455	8	TBD

b. FSE and Miscellaneous Equipment

Flight Support Equipment is minimal. Its mass is estimated to be zero.

c. Consumables and Containers

The xenon/methane gas mixture is housed in the gas reservoir and fill module. The filled module (at a pressure of 850 psia) has a mass of 1455 kg. The return (emptied) gas module has a mass of 732 kg.

d. Carriers

The gas module is transported in the STS and on the SS in a module carrier with mass = 950 kg and volume = TBD m^3.

14.4 Estimated Up/Down Mass on STS to Support LAMAR Strawman Servicing

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	0	0	0
ORU(s)	0	0	0
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	0	0	0
Equipment Carrier(s)	0	0	0
Subtotal, Equipment Mass Up	0	0	0
Subtotal, Equipment Mass Down	0	0	0
Consumables			
Consumables	723	0	723
Consumables Containers	732	0	732
Consumables Containers' Carriers	950	0	950
Subtotal, Consumables Mass Up	2405	0	2405
Subtotal, Consumables Mass Down	1682	0	1682
Total Mass Up	2405	0	2405
Total Mass Down	1682	0	1682

14.5 Estimated Up/Down Volume (m^3) on STS to Support LAMAR Strawman A Servicing

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	0	0	0
ORU(s)	0	0	0
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	0	0	0
Equipment Carriers	0	0	0
Equipment and Carriers Subtotal	0	0	0
Consumables			
Consumables	8	0	8
Consumables Containers	8	0	8
Consumables Containers Carriers	TBD	0	TBD
Total Volume Up	8 + TBD	0	8 + TBD
Total Volume Down	8 + TBD	0	8 + TBD

14.6 Storage on Space Station Required to Support Strawman LAMAR A Servicing

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	0	0	0
Volume (m^3)	0	0	0
Average Power (watts)	0	0	0
Temperature Range (^oC)	N.A.	N.A.	N.A.

Temporary Storage (If servicing changeout cannot occur during one shuttle SS visit)

Mass (kg)	2405	0	2405
Volume (m^3)	8 + TBD	0	8 + TBD
Average Power (watts)	TBD	TBD	TBD
Temperature Range (^oC)	TBD	TBD	TBD

14.7 LAMAR Strawman Servicing Power Estimates

	Operational Mode (Watts)		Servicing Mode (Watts)	
	AVG	MAX	AVG	MAX
Payload (Bus + Instruments)	TBD	TBD	TBD	TBD

14.8 LAMAR Strawman Servicing Times

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unloading servicing material from STS to SS	0:30^	0:30^	0:00^	0:30^
2. Transport servicing material to LAMAR	1:30^	3:00^	3:00^	1:30^
3. Gas Module Changeout	10:59^	16:29^	21:58^	5:30^
4. Transport servicing material from LAMAR	1:30^	3:00^	3:00^	1:30^
5. Loading of servicing material from SS to STS	0:30^	0:30^	0:00^	0:30^
TOTALS	14:49^	23:29^	27:58^	9:30^

14.9 OMV Flights in Support of LAMAR Strawmen Servicing Mission

None required; LAMAR is an attached payload in this study.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF LAMAR

15.1 LAMAR Milestone and Servicing Schedule (Nominal Mission Model)

Event	Location	Date	Comment
Payload Launch	STS/ETR	TBD	
1st Servicing	SS	Launch + 3 years	Strawman A
2nd Servicing	SS	Launch + 6 years	Strawman A
.		.	
.		.	
.		.	
Mission termination		TBD	

15.2 Summary of LAMAR Mass Considerations

a. LAMAR in Operational/Servicing Configurations

LAMAR Mass (dry): 6095 kg
Consumables Mass: 723 kg

LAMAR Mass (total): 6818 kg

b. LAMAR Servicing Materials

Event	Mass Up (kg)	Mass Down (kg)
Launch	6818	
1st Servicing	2405	1682
2nd-Nth Servicing	2405	1682
Payload Mission Termination		6818
Totals	TBD	TBD
Servicing Totals	TBD	TBD

c. LAMAR Servicing Storage Mass on Space Station*

Years from Launch	0	1	2	3
Storage Mass (kg)				
Unpressurized	0	0	0	2405
Pressurized	0	0	0	0
Total	0	0	0	2405

*The last three columns are repeated until mission termination.

15.3 Summary of LAMAR Volume Considerations

a. LAMAR Volume

Operational Configuration:	25.2 m^3
Servicing Configuration:	25.2 m^3
Storage/Transportation Configuration:	25.2 m^3

b. LAMAR Servicing Volumes Up and Down in STS*

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	25.2	
1st Servicing	8	8
2nd-Nth Servicing	8	8
Payload Mission Termination		25.2
Totals	TBD	TBD
Servicing Totals	TBD	TBD

*Excludes initial payload launch volume and mission termination flight volume, both chargeable to payload operations.

c. LAMAR Servicing Storage Volume on Space Station*

Years Since Launch	0	1	2	3
Storage Volume (m^3)				
Unpressurized	0	0	0	8
Pressurized	0	0	0	0
Total	0	0	0	8

*The last three columns are repeated until mission termination.

15.4 Summary of LAMAR Power Considerations

	AVG	MAX
Operational Power (watts)	TBD	TBD
Servicing Power (watts)	TBD	TBD
Storage Power, Servicing Materials (watts)	TBD	TBD

15.5 Summary of LAMAR Servicing Times*

Years Since Launch	0	1	2	3
Elapsed Time (hr:min)	0	0	0	20:19^
IVA Time (Crew-hr:min)	0	0	0	31:29^
EVA Time (Crew-hr:min)	0	0	0	38:38^
Total Crew Time (Crew-hr:min)	0	0	0	70:07^
Robotics Time (hr:min)	0	0	0	12:10^

*The last three columns are repeated until mission termination.

15.6 Summary of OMV Flights in Support of LAMAR Servicing

Not applicable.

REFERENCES

1. Telephone conversations with Mr. Gerald Austin, Smithsonian Astrophysical Observatory. (September and October, 1987)

2. Preliminary Lamar systems Specification (June 1,1987)

3. LAMAR/SHEAL Interface Control Document (May 15, 1987)

4. Mission Requirement Database (MRDB)

LASER COMMUNICATION ENGINEERING TEST (LASERCOM)

1.0 LASERCOM PROGRAM AND OPERATIONS INFORMATION

1.1 LASERCOM Points of Contact

Mr. George Knouse
NASA/HQ
Washington, D.C. 20546
(202) 453-1515

1.2 LASERCOM Objectives

The Laser Communication Engineering Test (LASERCOM) is a SS-attached payload which will test acquisition and tracking.

1.3 LASERCOM Servicing Schedule

- Launch Date: 1st quarter, 1995.
- First Space Station Service: None required.
- Servicing Interval: Not applicable.
- Operational Lifetime: 6 months to one year.

1.4 LASERCOM Orbital Parameters

LASERCOM is a SS-attached payload and, thus, has the same orbital parameters as the Space Station.

2.0 LASERCOM PHYSICAL CHARACTERISTICS

2.1 LASERCOM Description

LASERCOM consists of a telescope, a transmitter and receiver, and associated control electronics and support structure.

2.2 LASERCOM Physical Characteristics

Mass: 25 kg

Stowed Volume:	0.04 m^3
Length:	0.5 m
Diameter:	0.23 m
Deployed Volume:	0.04 m^3
Length:	0.5 m
Diameter:	0.23 m

2.3 LASERCOM Moving Parts and Special Features

LASERCOM employs an isolated precision telescope pointing mechanism.

2.4 LASERCOM Consumables

None required.

3.0 LASERCOM SERVICING INFORMATION

3.1 General Description for Servicing LASERCOM

LASERCOM requires no SS servicing.

3.2 LASERCOM Background

A laser communications package will fly on ACTS (Advanced Communications Technology Satellite) which will be launched to GEO in 1991. Beneficial tracking and acquisition experience can be achieved from LASERCOM communications to the ACTS package from three potential locations. Laser communications from LEO may be achieved from flight aboard the Orbiter in 1995 or 1996. It is, however, presently unclear whether LASERCOM will be flown in the Shuttle. Significant experience could be acquired from ground-based facilities if the LEO Shuttle flight does not occur. Finally, a SS-based LASERCOM (which could be the Shuttle instrument package with major modifications) will provide experience acquiring and tracking the GEO ACTS package and/or ground-based instrumentation. ACTS has a planned experiment phase of 2 years, with enough fuel for at least 4 years of operation. This databook discusses the SS-based LASERCOM, whose initial design will not be complete until the year 1988.

3.3 Primary Role of SS in Servicing LASERCOM

LASERCOM requires no SS-based servicing.

3.4 Primary SS Facilities Required for Servicing LASERCOM

LASERCOM requires no SS-based servicing.

3.5 Space Station Personnel Required for Servicing LASERCOM

LASERCOM requires no SS-based servicing.

3.6 Servicing Precautions for LASERCOM

LASERCOM requires no SS-based servicing.

3.7 OMV Flight Profile Support of LASERCOM Servicing

LASERCOM requires no OMV support.

4.0 LASERCOM SERVICING SAFETY CONSIDERATIONS

4.1 LASERCOM Hazardous Systems

None identified.

4.2 Servicing Safety Precautions for LASERCOM

LASERCOM will employ optics which must be protected from contaminants.

5.0 LASERCOM SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 LASERCOM Crew Convenience Features

TBD.

5.2 LASERCOM Mechanical Interfaces

TBD.

5.3 LASERCOM Umbilical Interfaces

TBD.

5.4 LASERCOM RF Communication Interface

TBD.

5.5 LASERCOM Thermal Interface

TBD.

6.0 LASERCOM SERVICING ENVIRONMENT

6.1 LASERCOM Pointing/Orientation Concerns

TBD.

6.2 LASERCOM Contamination Concerns

LASERCOM will employ optics which are sensitive to particulate and condensate contaminants.

6.3 LASERCOM Radiation Concerns

TBD.

7.0 LASERCOM SERVICING ACCOMMODATIONS

7.1 LASERCOM Equipment Access

TBD.

7.2 LASERCOM Modularity

TBD.

7.3 LASERCOM Automated Servicing

TBD.

7.4 LASERCOM Servicing in the Space Station Pressurized Modules

LASERCOM requires no pressurized servicing.

8.0 LASERCOM SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Ref.Section
ORUs (including SIs)	No	No	9.0
Flight Support Equipment	No	No	10.0
Other Equipment	No	No	10.0
Servicing Equipment Carrier(s)	No	No	12.0
Servicing Consumables			
Propellant(s)	No	No	11.0
container(s)	No	No	11.0
Cryogen(s)	No	No	11.0
container(s)	No	No	11.0
Liquids(s)	No	No	11.0
container(s)	No	No	11.0
Gas(es)	No	No	11.0
container(s)	No	No	11.0
Other(s)	No	No	11.0
container(s)	No	No	11.0
Servicing Consumables Carrier(s)	No	No	12.0

9.0 LASERCOM ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of LASERCOM ORUs

LASERCOM requires no SS-based servicing. No LASERCOM ORUs have been identified.

9.2 LASERCOM ORU Physical Characteristics

LASERCOM has no identified ORUs.

9.3 LASERCOM ORU Storage Requirements

Not applicable.

9.4 Other Environmental Requirements for LASERCOM ORUs

Not applicable.

10.0 LASERCOM FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 LASERCOM Flight Support Equipment (FSE)

LASERCOM requires no SS-based servicing. Thus no FSE is required for servicing.

10.2 LASERCOM FSE Physical Characteristics

Not applicable.

10.3 LASERCOM FSE Storage Requirements

Not applicable.

10.4 Miscellaneous Servicing Equipment

None required.

11.0 LASERCOM SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

LASERCOM requires no consumables.

11.2 Physical Characteristics

Not applicable.

11.3 Storage Requirements

Not applicable.

12.0 CARRIERS FOR LASERCOM SERVICING MATERIALS

12.1 Description of Carriers

LASERCOM requires no SS-based servicing and, thus, requires no servicing materials carrier.

12.2 STS and SS Carrier Interfaces

Not applicable.

12.3 Servicing Materials/Carrier Interfaces

Not applicable.

13.0 LASERCOM ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

This databook addresses no contingency servicing.

13.2 Preparatory Servicing Time Estimates

LASERCOM requires no SS-based servicing.

13.3 Principal Servicing Time Estimates

LASERCOM requires no SS-based servicing.

13.4 Close-Out Servicing Time Estimates

LASERCOM requires no SS-based servicing.

14.0 LASERCOM STRAWMAN SERVICING SCENARIO

14.1 LASERCOM Strawman Servicing Mission

LASERCOM requires no SS-based servicing.

14.2 LASERCOM Description

LASERCOM is described in Section 2.0.

14.3 Strawman Servicing Materials

LASERCOM requires no SS-based servicing.

14.4 Estimated STS Up/Down Mass to Support LASERCOM Servicing

LASERCOM requires no SS-based servicing.

14.5 Estimated STS Up/Down Volume to Support LASERCOM Servicing

LASERCOM requires no SS-based servicing.

14.6 Space Station Storage Required to Support LASERCOM Servicing

LASERCOM requires no SS-based servicing.

14.7 LASERCOM Strawman Servicing Power Estimate

LASERCOM requires no SS-based servicing.

14.8 LASERCOM Strawman Servicing Time Estimates

LASERCOM requires no SS-based servicing.

14.9 OMV Flights in Support of LASERCOM Strawman Servicing

LASERCOM requires no OMV support.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF LASERCOM

15.1 LASERCOM Milestone and Servicing Schedule

Event	Location	Date
Launch	KSC	1st quarter, 1995
Termination	-	1st quarter, 1996

15.2 Summary of LASERCOM Mass Considerations

a. LASERCOM Mass

Operational Mass: 25 kg

b. LASERCOM Mass Up and Down in STS

Event	Mass Up (kg)	Mass Down (kg)
Launch	25	0
Termination	0	25
Total	25	25
Servicing Total	0	0

c. LASERCOM Servicing Storage Mass on SS

LASERCOM requires no SS-based servicing.

15.3 Summary of LASERCOM Volume Considerations

a. LASERCOM Volume

Operational Volume: 0.04 m^3

b. LASERCOM Volume Up and Down in STS

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	0.04	0
Termination	0	0.04
Total	0.04	0.04
Servicing Total	0	0

c. LASERCOM Servicing Storage Volume on SS

LASERCOM requires no SS-based servicing.

15.4 Summary of LASERCOM Power Considerations

	Average	Maximum
LASERCOM Operational Power	TBD	TBD
LASERCOM Servicing Power	N.A.	N.A.
Storage Power, Servicing Materials	0 W	0 W

5.5 Summary of LASERCOM Servicing Time Estimates

LASERCOM requires no SS-based servicing.

15.6 Summary of OMV FLights in Support LASERCOM Servicing

LASERCOM requires no SS-based servicing and threfore does not require any OMV support.

REFERENCES

1. Discussions with Mr. George Knouse (September, 1987).

LASER ATMOSPHERIC WIND SOUNDER (LAWS): MISSION CODE SAAX236

1.0 LAWS PROGRAM AND OPERATIONS INFORMATION

1.1 LAWS Point of Contact

M.J. Donohoe
NASA/GSFC, Code 415
Greenbelt, Maryland 20771
(301) 286-6820

1.2 LAWS Objectives

The LAWS tropospheric wind sensing instrument will provide a direct measurement of the tropospheric wind field (via Doppler LIDAR techniques) to a sensitivity of 2 to 3 meters per second.

1.3 LAWS Milestone and Servicing Schedule

Launch:	1st quarter, 1998
First Space Station Service:	1st quarter, 2001
Servicing Interval:	3 years
Operational Lifetime:	5 years

1.4 LAWS Orbital Parameters

LAWS is an SS-attached payload and, thus, has the same orbital parameters as the Space Station.

2.0 LAWS PHYSICAL CHARACTERISTICS

2.1 LAWS Description

LAWS consists of a 1.25 meter scanning telescope, a scan mechanism, a laser system, and support electronics. The system may also require a radiator for thermal dissipation with a clear view to cold space. The radiator size is approximated at 16 m^2 (and is not shown in Figure LAWS-1). The telescope is canted at a 45 degree angle to the nadir and rotates at approximately 3 rpm with the option to "stop and stare."

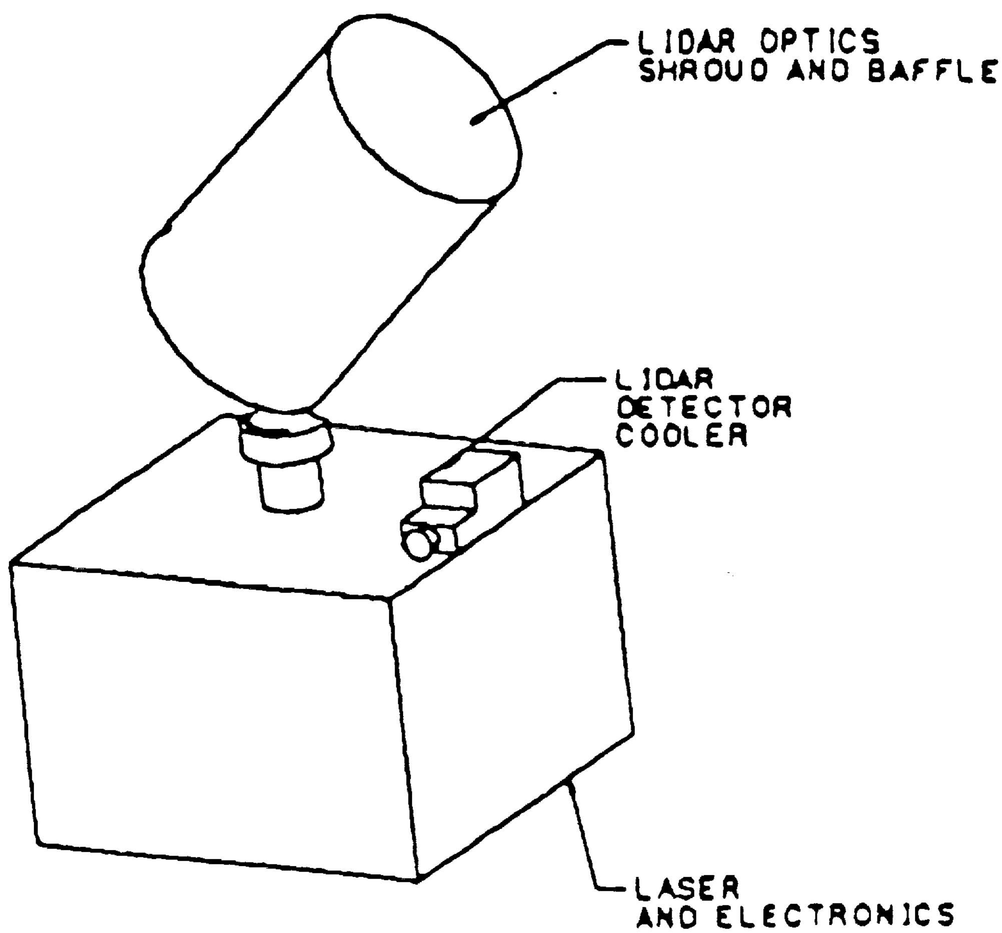

Figure LAWS-1. LAWS Operational Configuration

2.2 LAWS Physical Characteristics

Mass:	800 kg
Stowed Volume:	12.5 m^3
Length:	3.0 m
Width:	1.6 m
Height:	2.6 m
Deployed Volume:	52.0 m^3
Length:	3.8 m
Width:	3.8 m
Height:	3.6 m

2.3 LAWS Moving Parts and Special Features

The telescope scan mechanism includes a motor with associated bearings. A counter-rotating momentum wheel is used to compensate for the momentum of the rotating 150 kg telescope.

2.4 LAWS Consumables

LAWS utilizes an ethylene glycol/water solution in an internal thermal cooling fluid loop. This liquid, however, does not require replacement during LAWS' lifetime. Therefore, LAWS requires no consumables replenishment.

3.0 LAWS SERVICING INFORMATION

3.1 General Description for LAWS Servicing

The main concern for Space Station servicing of LAWS is the replacement of the CO_2 laser tube every three years. Three other ORUs have an estimated four year service life. Section 9 discusses these ORUs in more detail.

3.2 LAWS Background

The Doppler LIDAR techniques are flight-proven, having been demonstrated a number of times on NASA CV-990 flights.

3.3 Primary Role of Space Station in Servicing LAWS

The Space Station will be used to support the replacement of LAWS ORU(s). A temporary storage environment is required to maintain ORU survival temperatures until actual servicing of LAWS takes place.

3.4 Primary Space Station Facilities Required for Servicing LAWS

LAWS ORU(s) must be maintained in an environment conducive to survival for these components.

3.5 Space Station Personnel Required for Servicing LAWS

Two EVA and one IVA astronauts will be required to replace LAWS ORU(s).

3.6 Servicing Precautions for LAWS

LAWS optics are sensitive to condensable ionic, molecular, and particulate contaminants.

3.7 OMV Flight Profile Support of LAWS

LAWS servicing requires no OMV support.

4.0 LAWS SERVICING SAFETY CONSIDERATIONS

4.1 LAWS Hazardous Systems

LAWS presents no identifiable servicing safety hazards to Space Station personnel.

4.2 LAWS Servicing Safety Precautions

None identified.

5.0 LAWS SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 LAWS Crew Convenience Features

No servicing convenience features are identified.

5.2 LAWS Mechanical Interfaces

TBD.

5.3 LAWS Umbilical Interfaces

LAWS requires power and data transmission/reception lines to the Space Station. Having its own internal mechanical cooling system, LAWS does not require attachment to the Space Station thermal fluid cooling loop. Specific servicing power and data transfer rates are TBD.

5.4 LAWS RF Communication Interface

LAWS will require Space Station facilities for servicing and operational data transmission of approximately 100 kbps through the TDRSS network. A 3.5 Mbps option for infrequent raw data checks is desired. Real-time interaction of approximately 1 kbps is required to control laser transmitter pulse repetition and on/off operation for efficient usage.

5.5 LAWS Thermal Interface

LAWS has its own internal coolant system and does not require attachment to the Space Station thermal fluid loop.

6.0 LAWS SERVICING ENVIRONMENT

6.1 LAWS Pointing/Orientation Concerns

No specific servicing orientation constraints have been identified.

6.2 LAWS Contamination Concerns

LAWS is sensitive to ionic, molecular, and particulate contamination. LAWS optics are sensitive to condensable contaminants.

6.3 LAWS Radiation Concerns

TBD.

7.0 LAWS SERVICING ACCOMMODATIONS

7.1 LAWS Equipment Access

TBD.

7.2 LAWS Modularity

TBD.

7.3 LAWS Automated Servicing

The potential for automated servicing is TBD.

7.4 LAWS Servicing in the Space Station Pressurized Modules

LAWS require no pressurized Space Station service.

8.0 LAWS SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS-Provided	Ref. Section
ORU(s) (including SIs)	Yes	No	9.0
Flight Support Equipment	TBD	TBD	10.0
Other Equipment	No	No	10.0
Servicing Equipment Carriers	Yes	TBD	12.0

Servicing Consumables			
Propellant(s)	No	No	11.0
Container(s)	No	No	11.0
Cryogen(s)	No	No	11.0
Container(s)	No	No	11.0
Liquid(s)	No	No	11.0
Container(s)	No	No	11.0
Gas(es)	No	No	11.0
Container(s)	No	No	11.0
Other(s)	No	No	11.0
Container(s)			
Servicing Consumables Carrier(s)	No	No	12.0

9.0 LAWS ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of LAWS ORUs

Five LAWS ORUs have been identified. Four of these five are scheduled for replacement during LAWS' 5-year lifetime. The fifth ORU, the data processor, will be replaced only on a contingency basis.

ORU	Acronym	Servicing Interval	Servicing Interfaces
Data Processor	DP	6 years	Mechanical, Electrical
Electronics	EL	4 years	Mechanical, Electrical
Laser Head	LH	3 years	Fluid, Mechanical, Electrical
Power Supply	PS	4 years	Mechanical, Electrical
Scan Motor Assembly	SMA	4 years	Mechanical, Electrical

9.2 LAWS ORU Physical Characteristics

ORU	Mass (kg)	Dimensions (m)	Volume (m^3)
DP	25	0.33 x 0.19 x 0.02	0.0013
EL	22		0.06
LH	200	0.5 x 0.5 x 0.3	0.045
PS	100	0.8 x 0.4 x 0.2	0.064
SMA	75	0.3 x 0.3 x 0.2	0.012

9.3 LAWS ORU Storage Requirements

ORU	Operational Temperature	Survival Temperature
DP	+10 to +30 °C	-25°C to TBD
EL	+10 to +30 °C	-25°C to TBD
LH	+10 to +30 °C	-25°C to TBD
PS	+10 to +30°C	TBD to TBD
SMA	+10 to +30°C	TBD to TBD

9.4 Other Environmental Requirements for LAWS ORUs

None specified.

10.0 LAWS FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 LAWS Flight Support Equipment (FSE)

No unique flight support equipment is identified for the replacement of LAWS ORUs.

10.2 LAWS FSE Physical Characteristics

No unique FSE is identified.

10.3 LAWS FSE Storage Requirements

Not applicable.

10.4 LAWS Miscellaneous Servicing Equipment

None identified.

11.0 LAWS SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

LAWS requires no consumables replenishment.

11.2 Physical Characteristics

Not applicable.

11.3 Storage Requirements

Not applicable.

12.0 CARRIERS FOR LAWS SERVICING MATERIALS

12.1 Description of Carriers

The carrier required to transport the LAWS ORU(s) from the Earth to the Space Station is TBD.

12.2 STS and SS Carrier Interfaces

TBD.

12.3 Servicing Materials/Carrier Interfaces

TBD.

13.0 LAWS ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

Assumptions are made that the servicing times required to replace LAWS ORU(s) are directly related to those required by other missions' servicing ORU replacements according to ORU mass. (See Apppendix C for more detail.)

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1) Unload Servicing Materials from Orbiter	0:30^	0:30^	0:00^	0:30^
2) Transport ORU(s) to LAWS SS attachment point	1:30^	3:00^	3:00^	1:30^

13.3 Principal Servicing Time Estimates

ORU Replacement	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
DP	0:44^	1:06^	1:28^	0:22^
EL	0:42^	1:04^	1:25^	0:21^
LH	2:00^	3:00^	4:00^	1:00^
PS	1:16^	1:54^	2:32^	0:38^
SMA	1:05^	1:38^	2:10^	0:33^

13.4 Close-Out Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1) Transport ORU(s) from LAWS to SS Service Facility	1:30^	3:00^	3:00^	1:30^
2) Load Service Materials onto Orbiter	0:30^	0:30^	0:00^	0:30^

14.0 LAWS STRAWMAN SERVICING SCENARIOS

14.1 LAWS Strawman Servicing Mission

A single servicing scenario, Strawman A, is presented in this section. This servicing scenario assumes the changeout after 3 years of LAWS operations of the laser head, electronics, powers supply and scan motor assembly ORUs. Although the latter three ORUs have an estimated service life of 4 years, they are assumed to be changed out at the scheduled 3 year service interval. It is assumed that LAWS will operate for five years and, thus, the Data Processor ORU does not need to be replaced. Servicing materials will be brought from the Earth via the Orbiter to the SS Service Facility. They will then be unloaded and stored temporarily in unpressurized storage. The servicing materials will be transported from the storage facility to the SS-attached LAWS where servicing (ORU replacement) will take place. The changed-out ORUs and any other servicing materials will be transported back to the unpressurized storage facility before being loaded back onto the Orbiter for transport to the ground.

14.2 LAWS Description

LAWS is an Earth-viewing SS-attached payload. Its servicing-related physical characteristics are defined in Section 2.2.

14.3 Strawman Servicing Materials

ORU	Quantity	Mass	Volume
EL	1	22 kg	0.06 m^3
LH	1	200 kg	0.045 m^3
PS	1	100 kg	0.064 m^3
SMA	1	75 kg	0.012 m^3

14.4 Estimated Up/Down Mass on STS to Support LAWS Strawman Servicing

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
ORU(s)	397	0	397
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment Subtotal	397	0	397
Equipment Carrier(s)	220^	0	220^
Subtotal, Equipment Mass Up	620^	0	620^
Subtotal, Equipment Mass Down	620^	0	620^
Consumables			
Consumables	0	0	0
Consumables Containers	0	0	0
Consumables Containers' Carriers	0	0	0
Subtotal, Consumables Mass Up	0	0	0
Subtotal, Consumables Mass Down	0	0	0
Total Mass Up	620^	0	620^
Total Mass Down	620^	0	620^

14.5 Estimated Up/Down Volume on STS to Support LAWS Strawman Servicing

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	0	0	0
ORU(s)	0.18	0	0.18
Unique FSE	0	0	0
Misc. Equipment	0	0	0
Equipment and Carriers Subtotal	0.39^	0	0.39^
Consumables			
Consumables in Containers	0	0	0
Consumables, Containers, and Carriers	0	0	0
Total Volume Up	0.39^	0	0.39^
Total Volume Down	0.39^	0	0.39^

14.6 Storage on Space Station Required to Support LAWS Strawman Servicing

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	0	0	0
Volume (m^3)	0	0	0
Average Power (watts)	0	0	0
Temperature Range (°C)	-	-	-
Temporary Storage			
Mass (kg)	620^	0	620^
Volume (m^3)	0.39^	0	0.39^
Average Power (watts)	TBD	0	TBD
Temperature Range (°C)	-25°C to TBD	-	-25°C to TBD

14.7 LAWS Strawman Servicing Power Estimates

Operational Mode		Servicing Mode	
AVG	MAX	AVG	MAX
3000	TBD	400	600

14.8 LAWS Strawman Servicing Times

Strawman A

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unload Orbiter	0:30^	0:30^	0:00	0:30^
2. Transport Parts	1:30^	3:00^	3:00^	1:30^
3. Replace ORUs (EL, LH, PS, SMA)	3:24^	5:06^	6:48^	1:42^
4. Transport Parts	1:30^	3:00^	3:00^	1:30^
5. Load Orbiter	0:30^	0:30^	0:00	0:30^
TOTALS	7:24^	12:06^	12:48^	5:42^

14.9 OMV Flights in Support of LAWS Strawman Servicing

LAWS requires no OMV support.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF LAWS

15.1 LAWS Milestone and Servicing Schedule

Event	Location	Date
Launch	KSC	1st quarter, 1998
1st SS Service	SS Lower Boom	1st quarter, 2001
Termination		4th quarter, 2002

15.2 Summary of LAWS Mass Considerations

a. LAWS in Operational/Servicing Configurations

Servicing and Operational Mass: 800 kg

b. LAWS Servicing Mass Up and Down in STS

Event	Mass Up (kg)	Mass Down (kg)
Launch	800	0
1st SS Service	620^	620^
Termination	0	800
Total	1420^	1420^
Servicing Total*	620^	620^

* Servicing total does not include initial payload launch mass and final mission termination mass.

c. LAWS Servicing Storage Mass on Space Station

	Storage Mass (kg)		
Calendar Year	Unpressurized	Pressurized	Total
1995	0	0	0
1996	0	0	0
1997	0	0	0
1998	0	0	0
1999	0	0	0
2000	0	0	0
2001*	620^	0	620^
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	0	0	0

* 1st quarter

15.3 Summary of LAWS Volume Considerations

a. LAWS Volume
Servicing and Operational Volume: 52 m^3

b. LAWS Servicing Material Volume Up and Down in STS

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	12.5	0
1st SS Service	0.39^	0.39^
Termination	0	12.5
Total	12.89^	12.89^
Servicing Total*	0.39^	0.39^

* Servicing total does not include initial launch volume or final mission termination volume.

c. LAWS Servicing Storage Volume on Space Station

Calendar Year	Storage Mass (kg) Unpressurized	Pressurized	Total
1995	0	0	0
1996	0	0	0
1997	0	0	0
1998	0	0	0
1999	0	0	0
2000	0	0	0
2001*	0.39^	0	0.39^
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	0	0	0

* 1st quarter

15.4 Summary of LAWS Power Considerations

	Average	Maximum
LAWS Operational Power	3000 W	TBD
LAWS Servicing Power	400 W	600 W
Storage Power, Servicing Materials	TBD	TBD

15.5 Summary of LAWS Servicing Time Estimates

Calendar Year	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1995	0:00	0:00	0:00	0:00
1996	0:00	0:00	0:00	0:00
1997	0:00	0:00	0:00	0:00
1998	0:00	0:00	0:00	0:00
1999	0:00	0:00	0:00	0:00
2000	0:00	0:00	0:00	0:00
2001*	7:24^	12:06^	12:48^	5:42^
2002	0:00	0:00	0:00	0:00
2003	0:00	0:00	0:00	0:00
2004	0:00	0:00	0:00	0:00
2005	0:00	0:00	0:00	0:00

*1st quarter

15.6 Summary of OMV Flights in Support of LAWS Servicing
None required.

REFERENCES

1. Mission Requirements Data Base (MRDB), January, 1987, NASA/JSC.

2. Conversation with Mr. M. Donohoe, NASA/GSFC, October, 1987.

LARGE DEPLOYABLE REFLECTOR (LDR): MISSION CODE SAAX0020

1.0 LDR PROGRAM AND OPERATIONS INFORMATION

1.1 LDR Points of Contact

Dr. Paul Swanson
NASA/JPL
4800 Oak Grove Drive
Pasadena, California 91109
(818) 354-3273

1.2 LDR Objectives

LDR is a planned orbiting observatory whose objective is to conduct submillimeter-infrared astronomical observations of a wide variety of astrophysical phenomena throughout the spectral region between 30 and 1000 microns.

1.3 LDR Milestone and Servicing Schedule

Launch Date: 4th quarter, 2000; 2nd quarter, 2001.

First Space Station Service: 4th quarter, 2000.

Servicing Interval: 2 years.

Operational Lifetime: 15 years.

1.4 LDR Orbital Parameters

- Free-flyer.
- 700 km circular orbit.
- 28.5 degrees inclination.

2.0 LDR PHYSICAL CHARACTERISTICS

2.1 LDR Description

LDR will be brought to the Space Station in one or more shuttle loads where it will be assembled and tested. It will then be placed in operational orbit by the OMV, and perodically serviced. LDR is a 20 meter diameter filled-aperture reflecting telescope (See Figures LDR-1, LDR-2, and LDR-3), and is composed of the

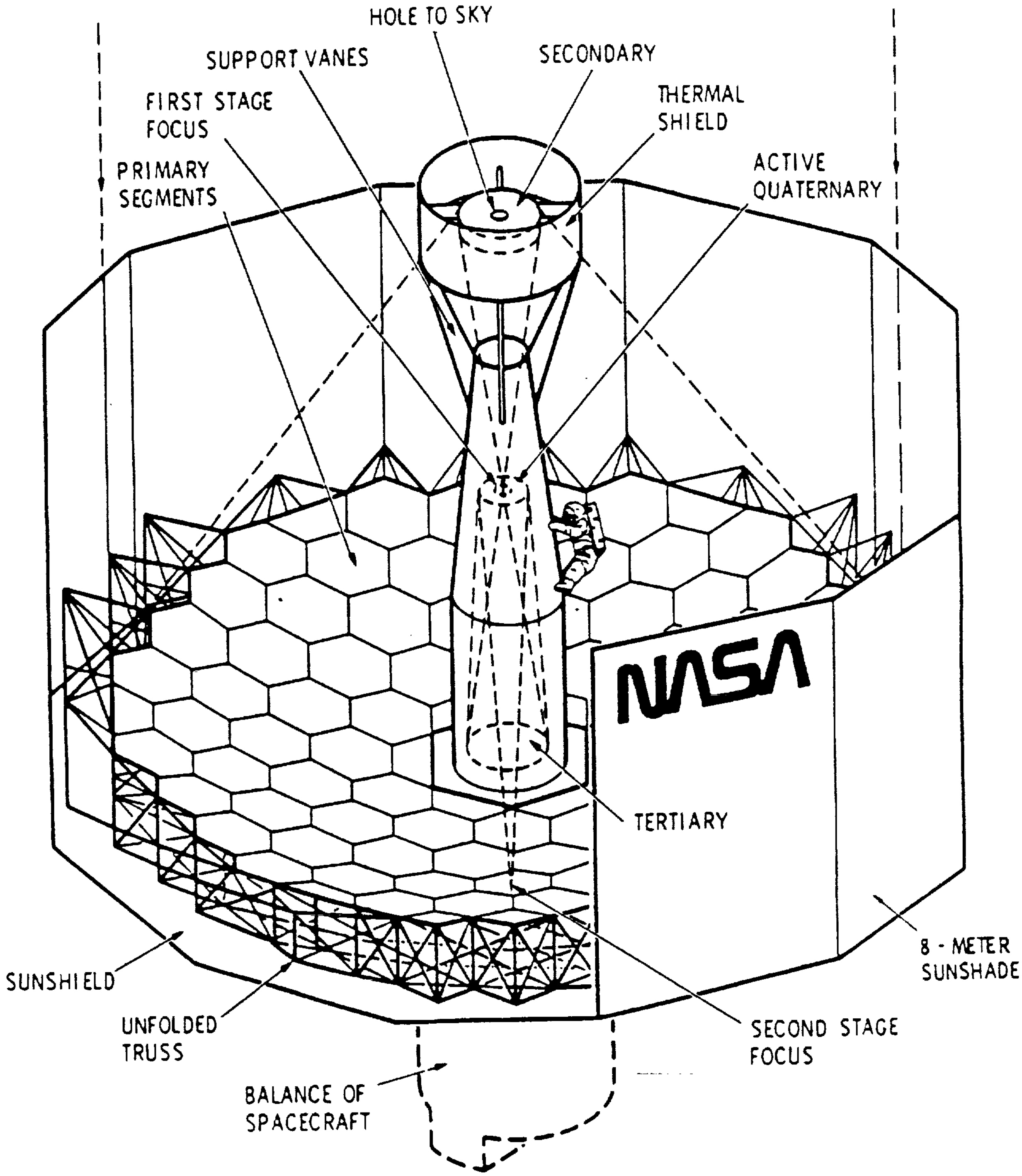

Figure LDR-1. LDR Telescope Configuration.

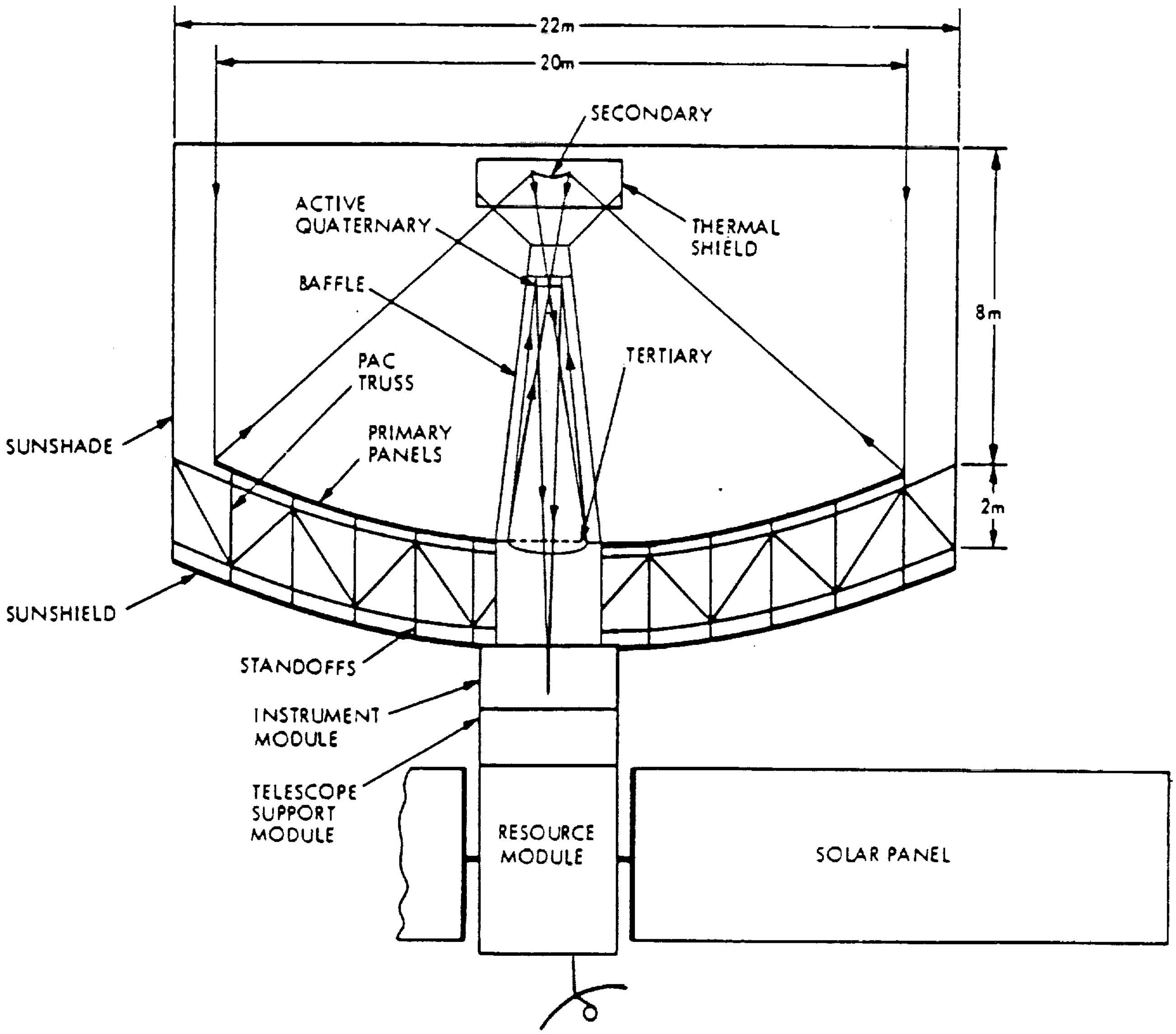

Figure LDR-2. Current JPL Concept.

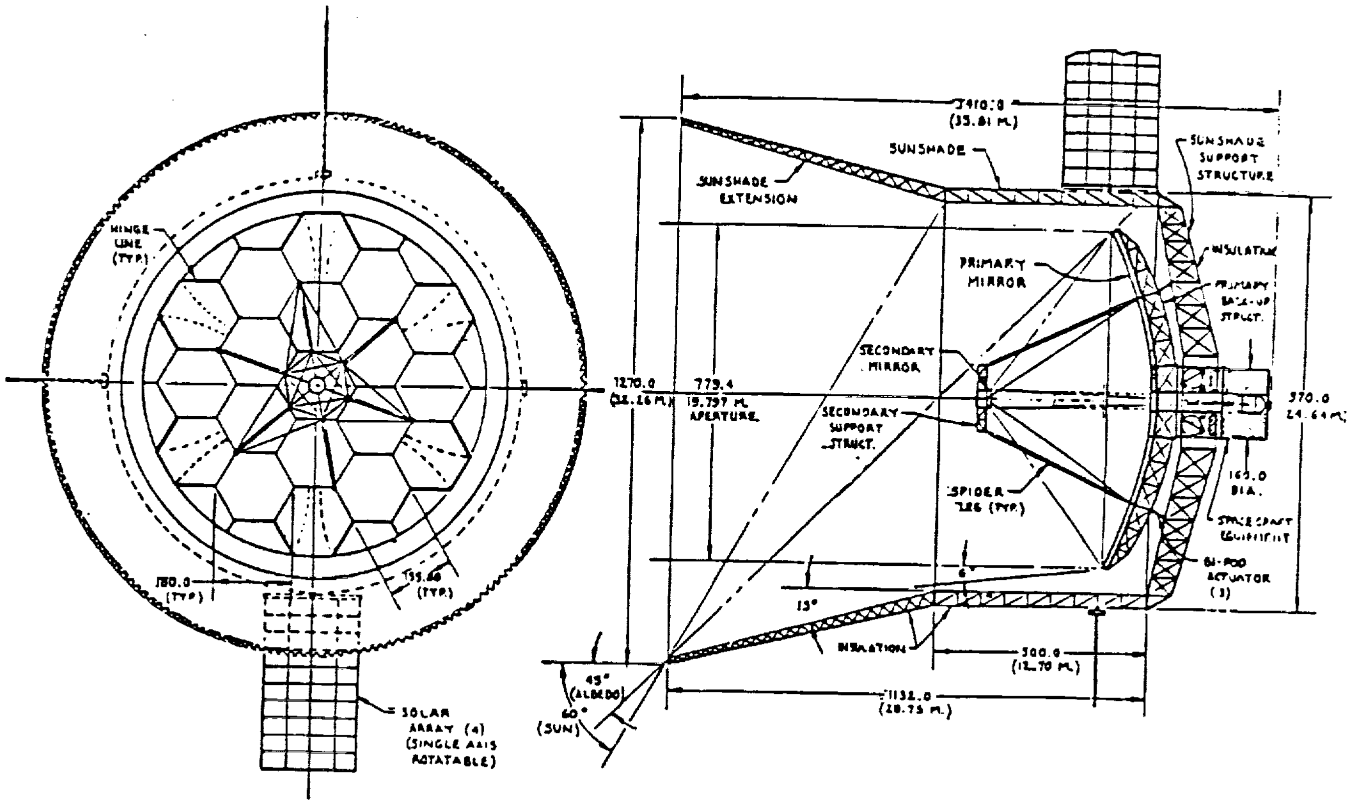

Figure LDR-3. Lockheed/Itec LDR Concept.

following 4 subsystems:

a. Optical System

- Reflector optics and support structure.
- Sunshade* (Provides thermal protection by surrounding the primary mirror and is approximately 8 meters in height).
- Adaptive optics sensors and controllers.
- Fine pointing sensors.

b. Instrument Module

- Science instrument assemblies.
- Fine and coarse pointing sensors.
- Cryogen dewars and mechanical refrigerators.

c. Telescope Support Module

- Stores housekeeping equipment required by instrument module and optical system.
- Contains all warm instrument electronics.
- Interface between payload and bus.

d. Resource Module (LDR Bus)

- Carrier platform for LDR.
- Provides power generation and preconditioning, power storage, telecommunications, coarse attitude control, and central communications and data handling.

2.2 LDR Physical Characteristics

a. Mass

- Total Dry:	29200 kg
- Total Wet:	30000 kg
- Optical System:	11272 kg
- Instrument Module:	2223 kg
- Telescope Support Module:	5655 kg
- Resource Module:	10081 kg
- Cryogen (Superfluid Helium):	800 kg

b. Dimensions

- Packaged in STS (1 or more flights required): Entire STS payload bay
- Optical System (Reflector, Sun shield): 13 x 22 m diameter
- Instrument, Telescope Support, and Resource Modules: TBD
- Solar Arrays (2): 160 m^2
- Solar Array Booms: TBD
- High Gain Antenna: 3 m diameter

c. Envelope

- SAs, HGA Deployed (Estimated): 22 m diameter (40 at solar arrays) x 40 m length.

2.3 LDR Moving Parts and Special Features

a. Solar Arrays (SA)

Proposed as a two wing configuration. SA type, dimensions, and deployment mechanisms are TBD.

b. High Gain Antenna System

Standard 3 m antenna for TDRSS communications.

c. Sun Shield

8 meter high shield around the circumference of the reflector to provide thermal protection of the primary mirror.

d. Control Moment Gyros

6 Skylab CMGs for LDR pointing and attitude control.

e. Quaternary Mirror

The LDR quaternary mirror will be servo-controlled for fine pointing control. Each of the 84 segments in the mirror will tilt and translate (up/down) to control the telescope wavefront.

2.4 LDR Consumables

The only consumable used by LDR is superfluid helium (800 kg).

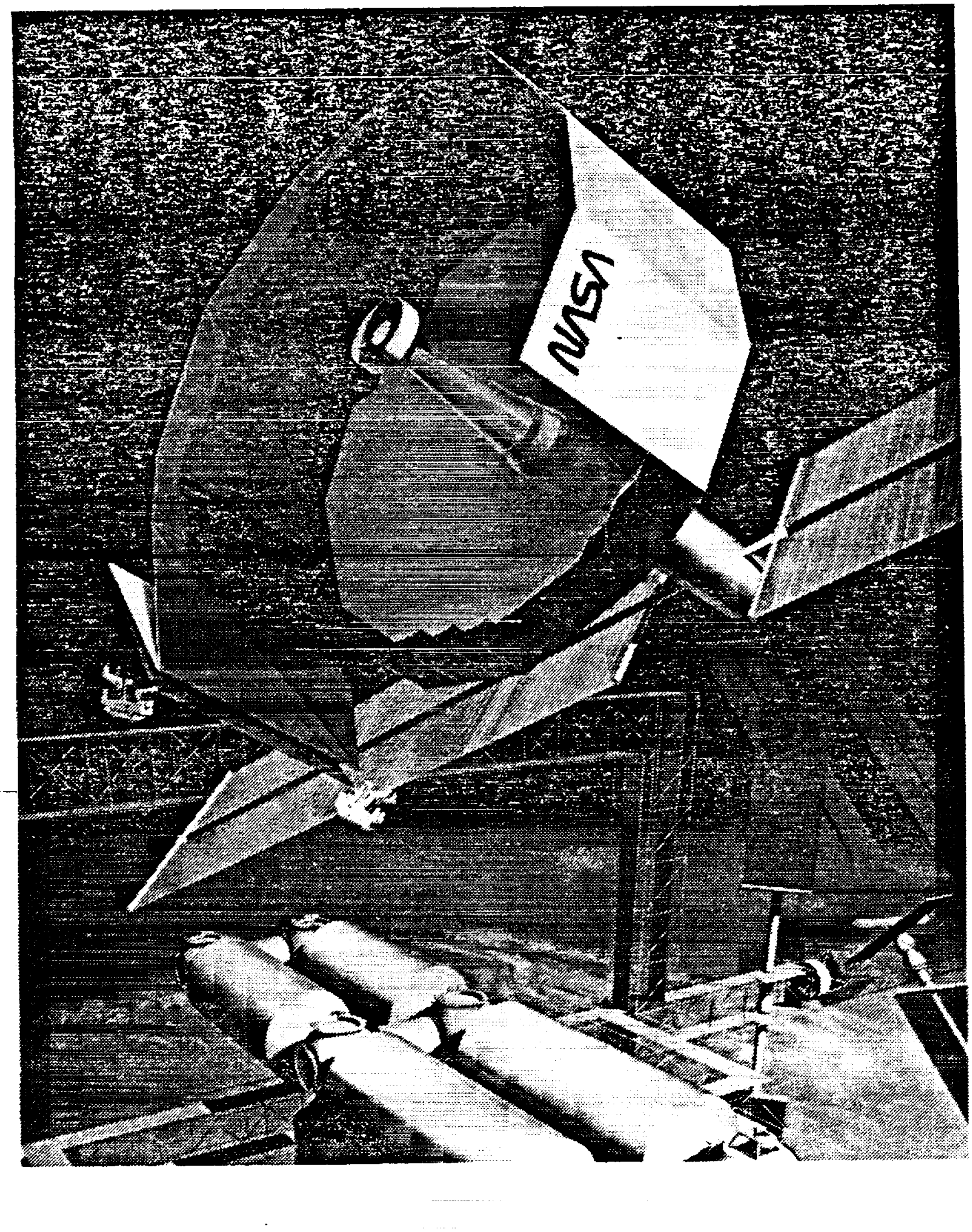

Figure LDR-4. LDR Assembly.

3.0 LDR SERVICING INFORMATION

3.1 General Description of LDR Servicing

LDR is expecting to require two shuttle launches to deliver the complete system to the Space Station. The first form of servicing that will occur for LDR is on-orbit assembly (Figure LDR-4). This will begin immediately after the first portion is launched, and continue through the second launch. The assembled first portion will remain attached to the Space Station until the second assembly is completed. At that time, LDR will be deberthed from the Station for operational checkouts. These checkouts will be performed at a distance of at least several kilometers from the Station. LDR, with no propellant, will remain in an inertially stable attitude while being controlled by large momentum wheels and magnetic unloading. Following successful checkouts, LDR will be taken to its operational orbit (700 km) by the OMV. The principal servicing activities during LDR's operational lifetime are replenishment of the telescope's liquid helium and changeout of science instruments; this will be done at approximately 2-year intervals.

LDR will become operational in the 2nd quarter, 2001. In-situ servicing with the OMV is the nominal servicing scenario. Development of Space Station robotic capabilities and an OMV Flight Telerobotic Servicer (FTS) capability, and the size of the LDR makes this the preferred method of LDR servicing. The OMV must be equipped to carry cryogens and replacement ORUs changeouts to the LDR.

3.2 LDR Background

No information available.

3.3 Primary Role of Space Station in Servicing LDR

The Space Station is essential for initial assembly of LDR. A selected area of the Space Station must be available for roughly

3 calender quarters while the assembly and check-out is taking place. The Space Station also provides a base from which the OMV can transport servicing materials in order to carry out in-situ servicing. The SS will be required to store replacement ORUs prior to a servicing mission, then provide OMV, communications, and crew support during the servicing mission.

3.4 Primary Space Station Facilities Required for Servicing LDR

- Storage volume for replacement ORUs.
- OMV, with FTS.
- Area in which LDR can be assembled at the station.

3.5 Space Station Personnel Required for Servicing LDR

3 Space Station payload servicing personnel.

3.6 Servicing Precautions for LDR

- Contact with primary truss or panels could cause misalignment.
- Quaternary mirror assembly is very sensitive to physical damage.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of LDR

The nominal usage of the OMV would be for in-situ servicing, along with re-boost and possible contingency return. The OMV will also be used for the initial placement of LDR in its orbit after assembly.

4.0 LDR SERVICING SAFETY CONSIDERATIONS

4.1 LDR Hazardous Systems

- Instrument cryogens (800 kg liquid helium).
- Focused solar energy.

4.2 LDR Servicing Safety Precautions

None specified.

5.0 LDR SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 LDR Crew Convience Features

LDR will be designed to accomodate aids for EVA access.

5.2 LDR Mechanical Interfaces

- OMV.
- FTS
- MRMS.
- No other information available.

5.3 LDR Umbilical Interfaces

a. Power
   - Servicing power requirements are TBD.

b. Data
   - Servicing data rates are TBD.

c. Fluids
   - Intake Quick Disconnect (QD) fittings for cryogens. Specific are TBD.

5.4 LDR RF Communication Interface

a. Forward Link (TDRSS to LDR)
   - Servicing requirements are TBD.
   - Operational CMD rate 1 kbps.

b. Return Link (LDR to TDRSS)
   - Servicing requirements are TBD.
   - Operationally, 500 kbps science and engineering data.

5.5 LDR Thermal Interface

- LDR temperature must be maintained between -125^{o}C and -75^{o}C during operating periods.
- LDR temperature must be maintained between 0^{o}C and 20^{o}C during non-operating periods.

- LDR's heat rejection during operational periods is 5 kw; heat rejection during non-operational periods is 1 kw.

6.0 LDR SERVICING ENVIRONMENT

6.1 LDR Pointing/Orientation Constraints

a. Exposure to Light

- LDR cannot point within 90 degrees of sun, or 45 degrees of the Earth's limb.
- LDR's x-axis is always perpendicular to sunline.
- Telescope rotates about z- and x- axis for targeting.
- During assembly, primary reflector must be protected against direct sunlight.

b. Thermal Control

- Primary optics must be maintained at less than 200 degrees Kelvin; secondary optics must be maintained at less than 125 degrees Kelvin.
- LDR employs thermal control surfaces, e.g., aluminized foil and black and white paints.

6.2 LDR Contamination Concerns

- Atomic oxygen erosion of graphite/epoxy will occur at Space Station altitudes, but is less of a problem at 700 km.
- Optical surfaces may need a contamination shroud to prevent condensation of volatiles if servicing is performed in the location of the Space Station.
- During STS Transportation, the main hazards to LDR include humidity and oxygen, dynamic loading, and fracture control.

6.3 LDR Radiation Concerns

None identified.

7.0 LDR SERVICING ACCOMMODATIONS

7.1 LDR Equipment Access

TBD.

7.2 LDR Modularity

The instrument module has been designated for EVA changeout. The entire module, or individual instruments, will be replaced.

7.3 LDR Automated Servicing

Automated servicing is the nominal scenario. In-situ servicing may be the best means of servicing, thus requiring an OMV with FTS. The SS robotics may also be needed for loading and unloading of servicing materials.

7.4 LDR Servicing in the Space Station Pressurized Modules

None required.

8.0 LDR SERVICING MATERIALS CHECKLIST

Servicing Equipment	Required	SS Provided	Comments	Ref. Section
ORU(s) (including SIs)	yes	no		9.0
Flight Support Equipment	yes	no		10.0
Other Equipment	yes	yes	OMV, FTS	10.0
Servicing Equipment Carrier(s)	yes	no		12.0
Servicing Consumables				
Propellant(s)	no	no		11.0
container(s)	no	no		11.0
Cryogen(s)	yes	yes	Superfluid Helium	11.0
container(s)	no	no		11.0
Liquids(s)	no	no		11.0
container(s)	no	no		11.0
Gas(es)	no	no		11.0
container(s)	no	no		11.0
Other(s)	no	no		11.0
container(s)	no	no		11.0
Servicing Consumables Carrier(s)	no	no		12.0

9.0 LDR ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of LDR ORUs

a. Primary
Likely candidates are LDR bus subsystem modules or subsystem components, LDR instruments, and cryogens.

b. Secondary
TBD.

9.2 LDR ORU Physical Characteristics

- Mass : 400 kg
- Volume : 3.0 m^3

9.3 LDR ORU Storage Requirements

- Storage Mass : 400 kg
- Storage Volume : 3.0 m^3
- Power Requirements : TBD

9.4 Other Enivronmental Requirements for LDR ORUs

Purge required for instrument units.

10.0 LDR FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 LDR Flight Support Equipment (FSE)

FSE is currently being defined. Some FSE will be for external use, and includes items such as sensor and radiator covers, mission-unique tooling, and mission-unique cabling.

10.2 LDR FSE Physical Characteristics

No information available.

10.3 LDR FSE Storage Requirements

Number	Storage mass (kg)	Volume (m^3)	Temperature(^oC)	Power (kW)
1	100.0	1.0	TBD	TBD

10.4 Miscellaneous Servicing Equipment

No information available.

11.0 LDR SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

The only consumable used by LDR is liquid helium. The helium is used to keep the instruments and secondary optics below their ambient temperatures. Every two years LDR must be replenished with 800 kg of helium. Liquid helium is to be stored permanently on the Space Station, therefore the orbiter will not have to transport helium for every servicing mission.

11.2 Physical Characteristics

a. Liquid Helium:

- Mass : 800 kg
- Volume : 5000 L
- Storage Pressure : TBD

11.3 Storage Requirements

No information available.

12.0 CARRIERS FOR LDR SERVICING MATERIALS

12.1 Description of Carriers

LDR Carriers are used to transport servicing materials on the STS and then used as temporary storage on the SS.

- Mass : 340 kg
- Volume : 4.0 m^3

12.2 STS and SS Carrier Interfaces

No information available.

12.3 Servicing Materials/Carrier Interfaces

TBD.

13.0 LDR ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

No information available.

13.2 Preparatory Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unloading Servicing Material from STS to SS	0:30^	0:30^	0:00^	0:30^
2. Loading Servicing Materials from SS to OMV	0:30^	0:30^	0:00^	0:30^

13.3 Principal Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Assembly	130:00	130:00	225:00	56:15^
2. ORU Changeout	TBD	TBD	TBD	TBD
3. Liquid Helium Replenishment	TBD	TBD	TBD	TBD

13.4 Close-out Servicing Time Estimates

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Deberthing of LDR from SS	1:00	1:00	0:00	0:30
2. Loading of Servicing Material from SS to STS	0:30^	0:30^	0:00^	0:30^
3. Unloading of Servicing Materials from OMV to SS	0:30^	0:30^	0:00^	0:30^

14.0 LDR STRAWMAN SERVICING SCENARIO

14.1 LDR Strawman Servicing Mission

Three distinct strawman scenarios exist for LDR. The first, strawman A, is on-orbit assembly. LDR will be transported to the Station in two packages and assembly will begin immediately after the first launch. The second scenario, strawman B, is a continuation of strawman A. The assembly is continued through strawman B, but seperate servicing times are involved with the deberthing of LDR for the Station. The third scenario, strawman C, is liquid helium replenishment as well as ORU changeout. The ORUs will be transported to the Space Station in the orbiter and the liquid helium is assumed to be available at the SS. The OMV will then transport these materials for in-situ servicing.

14.2 LDR Description

LDR's servicing configuration is the same as its operational configuration.

14.3 Strawman Servicing Materials

a. ORUs

Number	Mass (kg)	Volume (m^3)	Power (kW)
1	400	3.0	TBD

b. FSE and Miscellaneous Equipment

No information available.

c. Consumables and Containers

Liquid helium is required. An OMV with the appropriate equipment to support cryogen transfer to LDR is assumed to be available.

14.4 Estimated Up/Down Mass on STS to Support LDR Strawman Servicing

a. Strawman A

None required.

b. Strawman B

None required.

c. Strawman C

SERVICING MATERIAL	MASS, UNPRESSURIZED TRANSPORT (kg)	MASS, PRESSURIZED TRANSPORT (kg)	MASS, TOTAL (kg)
Equipment			
SI(s)	0	0	0
ORU(s)	400	0	400
Unique FSE	100	0	100
Misc. Equipment	0	0	0
Equipment Subtotal	500	0	500
Equipment Carrier(s)	340	0	340
Subtotal, Equipment Mass Up	840	0	840
Subtotal, Equipment Mass Down	840	0	840
Consumables*			
Consumables	0	0	0
Consumables Containers	0	0	0
Consumables Containers' Carriers	0	0	0
Subtotal, Consumables Mass Up	0	0	0
Subtotal, Consumables Mass Down	0	0	0
Total Mass Up	840	0	840
Total Mass Down	840	0	840

* LDR requires liquid helium, however, this is assumed to be available from the Space Station as a Standard Service and therefore is not chargeable to the payload.

14.5 Estimated Up/Down Volume on STS to Support LDR Strawman Servicing

a. Strawman A
None required.

b. Strawman B
None required.

c. Strawman C

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	0	0	0
ORU(s)	3.0	0	3.0
Unique FSE	1.0	0	1.0
Misc. Equipment	0	0	0
Equipment Subtotal	4.0	0	4.0
Equipment Carriers	4.0	0	4.0
Equipment and Carriers Subtotal	8.0	0	8.0
Consumables*			
Consumables in Containers	0	0	0
Consumables, Containers, and Carriers	0	0	0
Total Volume Up	8.0	0	8.0
Total Volume Down	8.0	0	8.0

* LDR requires liquid helium; however, this is assumed to be available from the Space Station as a Standard Service and therefore is not chargeable to the payload.

14.6 Storage on Space Station Required to Support LDR Strawman Servicing

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	0	0	0
Volume (L)	0	0	0
Average Power (watts)	0	0	0
Temperature Range (^oC)	-	-	

Temporary Storage			
Mass (kg)	840	0	840
Volume (m^3)	8.0	0	8.0
Average Power (watts)	TBD	0	TBD
Temperature Range (^oC)	TBD	-	

14.7 LDR Strawman Servicing Power Estimates

	Operational Mode		Servicing Mode	
	AVG	MAX	AVG	MAX
LDR (Bus + Instruments)	7000	TBD	TBD	TBD

14.8 LDR Strawman Servicing Times

a. Strawman A

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
Assembly	130:00	130:00	225:00	56:15^

b. Strawman B

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Assembly	130:00	130:00	225:00	56:15^
2. LDR Deberthing from SS	1:00	1:00	0:00	0:30

c. Strawman C

Activity	Elapsed Time (hr:min)	IVA Time (Crew-hr:min)	EVA Time (Crew-hr:min)	Robotics Time (hr:min)
1. Unloading Servicing Material from STS to SS	0:30^	0:30^	0:00^	0:30^
2. Loading of Servicing Materials from SS to OMV	0:30^	0:30^	0:00^	0:30^
3. ORU changeout	TBD	TBD	TBD	TBD
4. Liquid Helium Replenishment	TBD	TBD	TBD	TBD
5. Unloading of Servicing Materials from OMV to SS	0:30^	0:30^	0:00^	0:30^
6. Loading of Servicing Materials from SS to STS	0:30^	0:30^	0:00^	0:30^

14.9 OMV Flights in Support of LDR Strawman Servicing Missions

Strawman Mission	Purpose of Flight	Number of Flights
Strawman A	N.A.	0
Strawman B	Initial Deployment	1
Strawman C	In-situ servicing, reboost	1

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF LDR

Overall requirements are summarized through the year 2005 only. Additional information may sometimes be included for completeness.

15.1 LDR Milestone and Servicing Schedule (Nominal Mission Model)

Event	Location	Date	Comment
LDR Launch	STS	4th quarter, 2000; 2nd Quarter, 2001	
1st Servicing	SS	4th quarter, 2000	A
2nd Servicing	SS	2nd quarter, 2001	B
3rd Servicing	in-situ	2nd quarter, 2003	C
4th Servicing	in-situ	2nd quarter, 2005	C
5th Servicing	In-situ	2nd quarter, 2007	C
6th Servicing	In-situ	2nd quarter, 2009	C
7th Servicing	In-situ	2nd quarter, 2011	C
8th Servicing	In-situ	2nd quarter, 2013	C
9th Servicing	In-situ	2nd quarter, 2015	C
Payload Mission Termination		2nd quarter, 2016	

15.2 Summary of LDR Mass Considerations

a. LDR Mass in Operational/Servicing Configuration

LDR Mass (dry): 29200 kg
Consumables Mass: 800 kg

LDR Mass (total): 30000 kg

b. LDR Servicing Mass Up and Down in STS

Event	Mass Up (kg)	Mass Down (kg)
Launch (1)	15000	
Launch (2)	15000	
1st Servicing	0	0
2nd Servicing	0	0
3rd Servicing	840	840
4th Servicing	840	840
Totals	31680	1680
Servicing Totals	1680	1680

c. LDR Servicing Storage Mass on Space Station

Calendar Year	95	96	97	98	99	00	01	02	03	04	05
Storage Mass (kg)											
Unpressurized	0	0	0	0	0	0	0	0	840	0	840
Pressurized	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	840	0	840

15.3 Summary of LDR Volume Considerations

a. LDR Volume

LDR Volume, Operational Configuration: 15000 m^3
LDR Volume, Servicing Configuration: 15000 m^3
LDR Volume, Storage/Transportation Configuration: 300 m^3 (150 m^3 per STS flight)

b. LDR Servicing Volumes Up and Down in STS

Event	Volume Up (m^3)	Volume Down (m^3)
Launch (1)	150.0	
Launch (2)	150.0	
1st Servicing	0	0
2nd Servicing	0	0
3rd Servicing	8.0	8.0
4th Servicing	8.0	8.0
Totals	316.0	16.0
Servicing Totals	16.0	16.0

c. LDR Servicing Storage Volume on Space Station

Calendar Year	95	96	97	98	99	00	01	02	03	04	05
Storage Volume (m^3)											
Unpressurized	0	0	0	0	0	0	0	0	8.0	0	8.0
Pressurized	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	0	0	8.0	0	8.0

15.4 Summary of LDR Power Considerations

	AVG	MAX
Operational Power (watts)	7000	TBD
Servicing Power (watts)	TBD	TBD
Storage Power, Servicing Materials (watts)	TBD	N.A.

15.5 Summary of LDR Servicing Time Estimates

Calendar Year	95	96	97	98	99	00	01	02	03	04	05	Total
Elapsed Time (hr:min)	0	0	0	0	0	130:00	131:00	0	2:00 + TBD	0	2:00 + TBD	263:00 + TBD
IVA Time (Crew-hr:min)	0	0	0	0	0	130:00	131:00	0	2:00 + TBD	0	2:00 + TBD	263:00 + TBD
EVA Time (Crew-hr:min)	0	0	0	0	0	225:00	225:00	0	TBD	0	TBD	450:00 + TBD
Total Crew Time (hr:min)	0	0	0	0	0	355:00	356:00	0	2:00 + TBD	0	2:00 + TBD	713:00 + TBD
Robotics Time (hr:min)	0	0	0	0	0	56:15^	56:15^		2:00 + TBD	0	2:00 + TBD	114:30^ +TBD

15.6 Summary of OMV Flights in Support of LDR Servicing

Calendar Year	95	96	97	98	99	00	01	02	03	04	05	TOTAL
Number of OMV Flights	0	0	0	0	0	0	1*	0	1**	0	1**	3

* 2nd quarter - deployment
** 2nd quarter - in-situ servicing/boost.

REFERENCES

1. Interview with Dr. Paul Swanson, JPL, July 16, 1987.

2. "Space Station Staging of the Large Deployable Reflector (LDR), Interim Requirements Report," Richard Mattingly, JPL, Pasadena, Californa.

LIFE SCIENCES RESEARCH FACILITIES (LSRF): MISSION CODE SAAX307

1.0 LSRF PROGRAM AND OPERATIONS INFORMATION

1.1 LSRF Points of Contact

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1.2 LSRF Objectives

The objective of the Life Sciences Research Facilities (LSRF) is to provide a national laboratory in space for basic research in the Life Sciences and to assure the health, welfare, and adaptation of man during long duration space activity. This endeavor will necessitate the implementation of life science experiments involving human, animal, plant, and cellular organisms. The pressurized research laboratory will allow Life Scientists to study the effects of long term exposure to microgravity and will increase our understanding of this foreign environment on basic life processes.

1.3 LSRF Milestone and Servicing Schedule

Launch Date:	First Quarter, 1995
First Space Station Service:	First Quarter, 1995
Servicing Interval:	- 3 months (from Logistics Module for consumables replenishment and rack equipment changeout) - Continuously for animal specimen maintenance
Operational Lifetime:	20-30 years

1.4 LSRF Orbital Parameters

The LSRF is contained within the pressurized U.S. Laboratory (USL) module and the resource nodes attached directly to the Space Station (SS).

2.0 LSRF PHYSICAL CHARACTERISTICS

2.1 LSRF Description

The desired fully outfitted Life Science Research Facilities will consist of 39 m^3 of equipment rack volume contiguously contained within the pressurized volume of the U.S. Laboratory module and its attached resource nodes, and a separate 4.0 m centrifuge to be launched later in the program and contained within a shortened module or a resource node. A candidate rack layout is shown in Figure LSRF-1. Over 30 Biomedical Research Projects (BmRP), which use human crew members as subjects, and over 40 Biological Research Projects (BRP), which use non-human subjects such as rodents, primates, and plants, are planned for investigation concerning the disciplines of: calcium homeostasis; cardiovascular function; muscle, exercise, and pulmonary physiology; radiation effects; endocrinology and fluid electrolyte studies; behavioral research; hematology; immunology; neurosciences; pharamacokinetics; microbiology; metabolic regulation and cell biology; plant physiology; and reproduction and development.

Operation and servicing of the life science experiments is to be conducted within the IVA environment of the pressurized modules. LSRF resupply, which includes transport of supplies, animals, and equipment, will be handled via the Logistics Module.

At the present time, the objectives, equipment, performance, and preliminary protocol of each candidate experiment have been developed and demonstrated in the RMOAD for the LSRF (see Bibliography). Current LSRF outfitting plans call for a nine-phase build of the complete LSRF capability over a six year period employing nine dedicated Orbiter outfitting flights along with standard 90-day logistics resupply flights. The actual

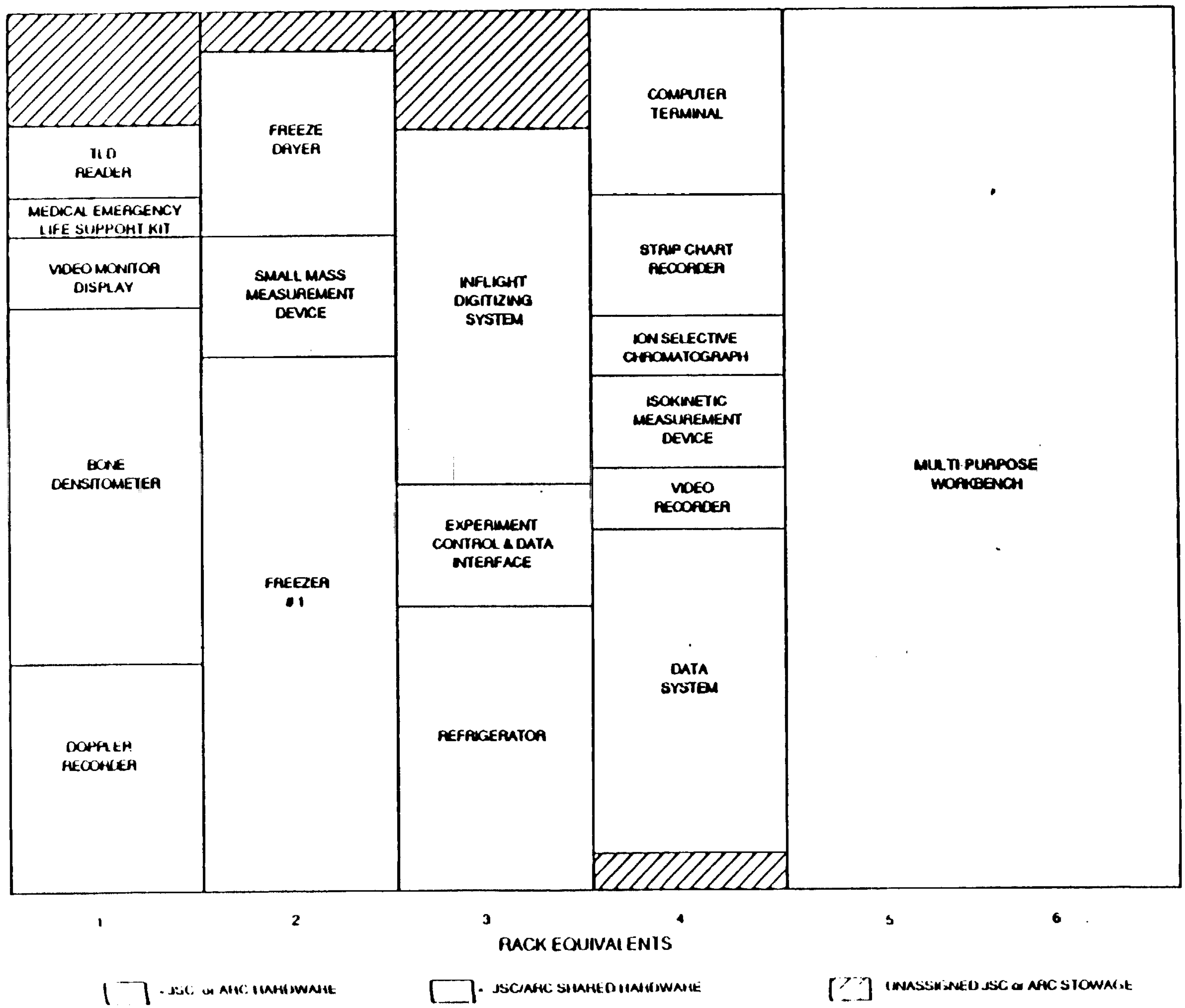

Figure LSRF-1. LSRF Rack Layout

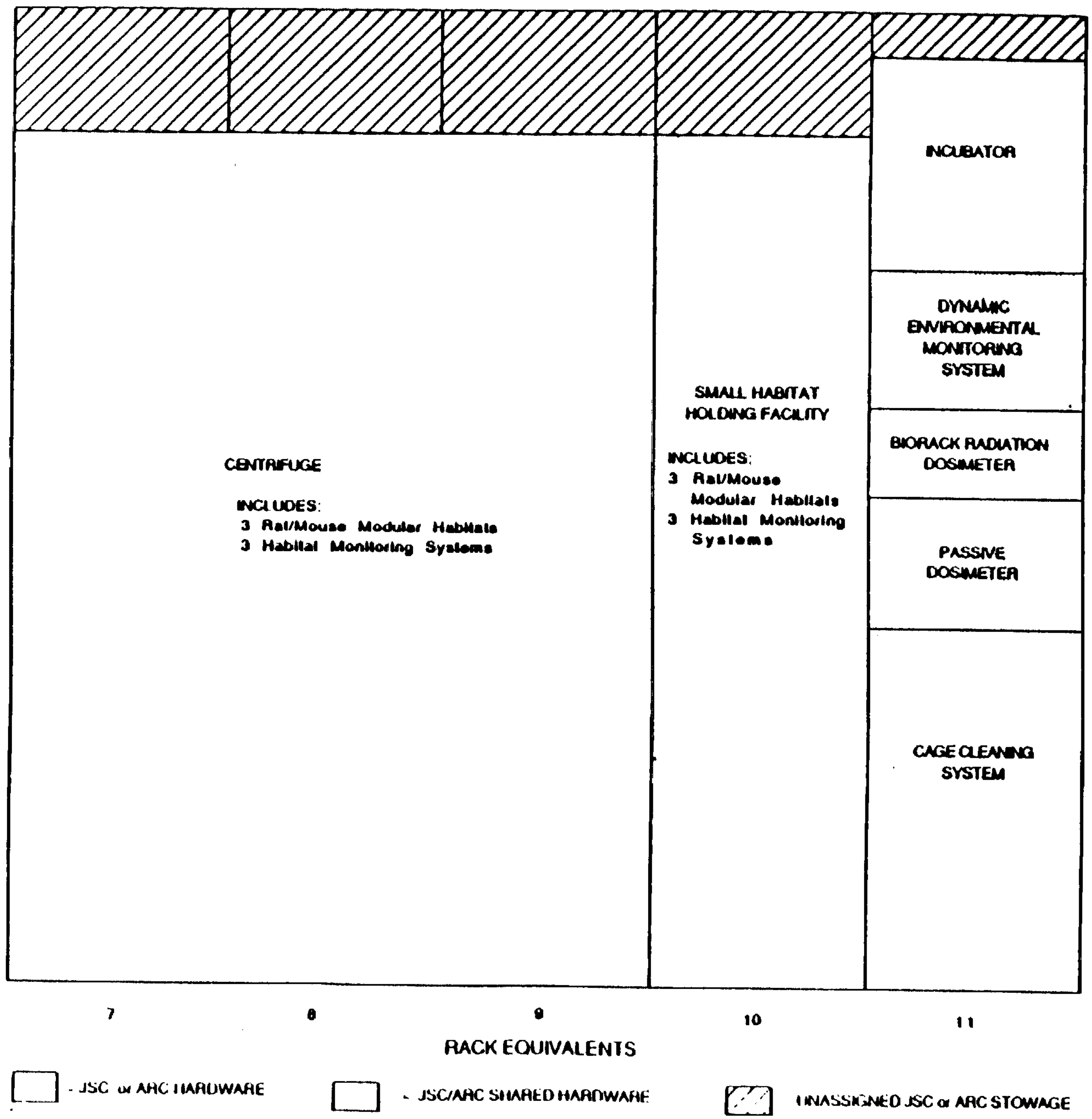

Figure LSRF-1. Rack Layout (Continued)

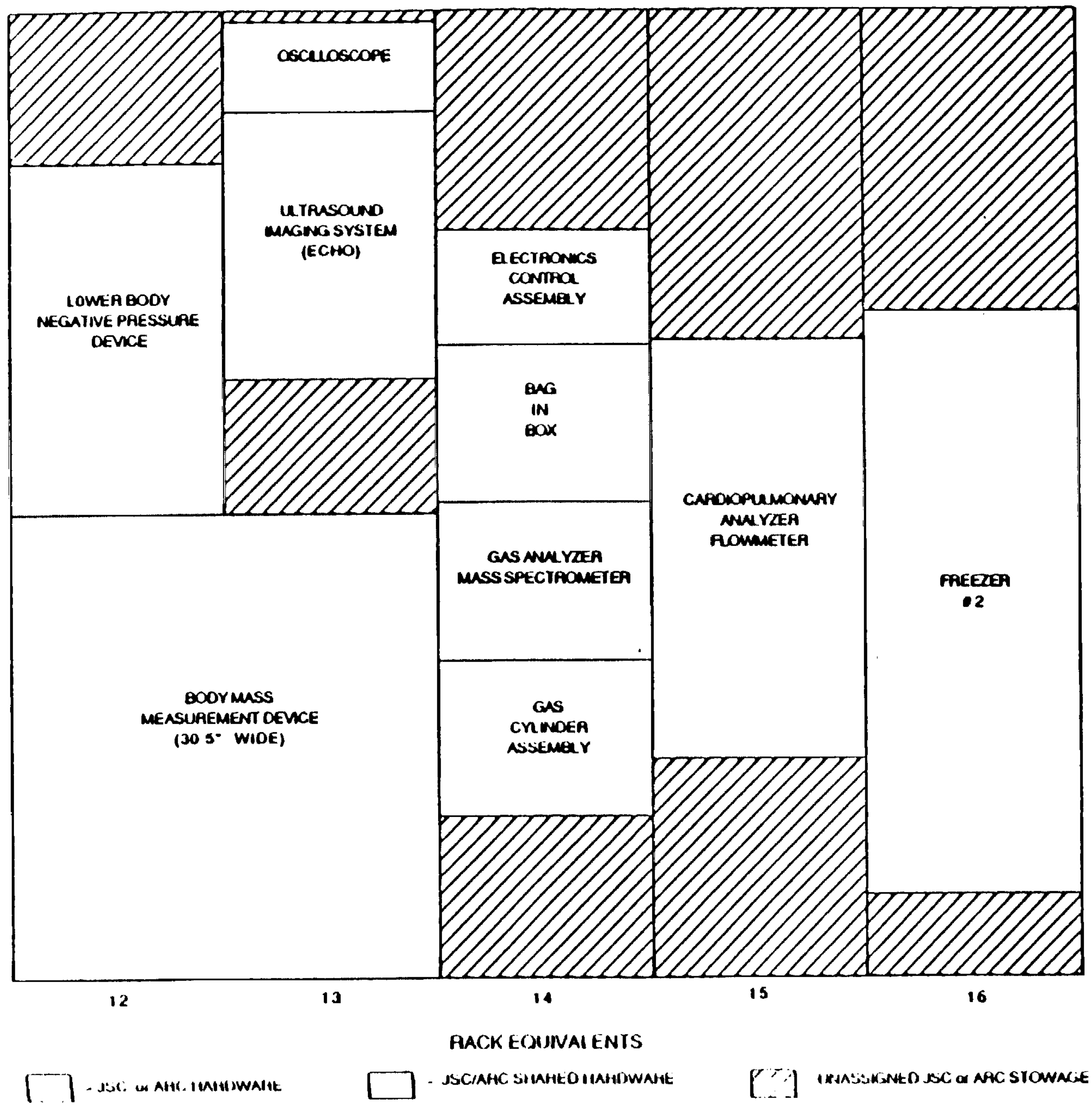

Figure LSRF-1 Rack Layout (Continued)

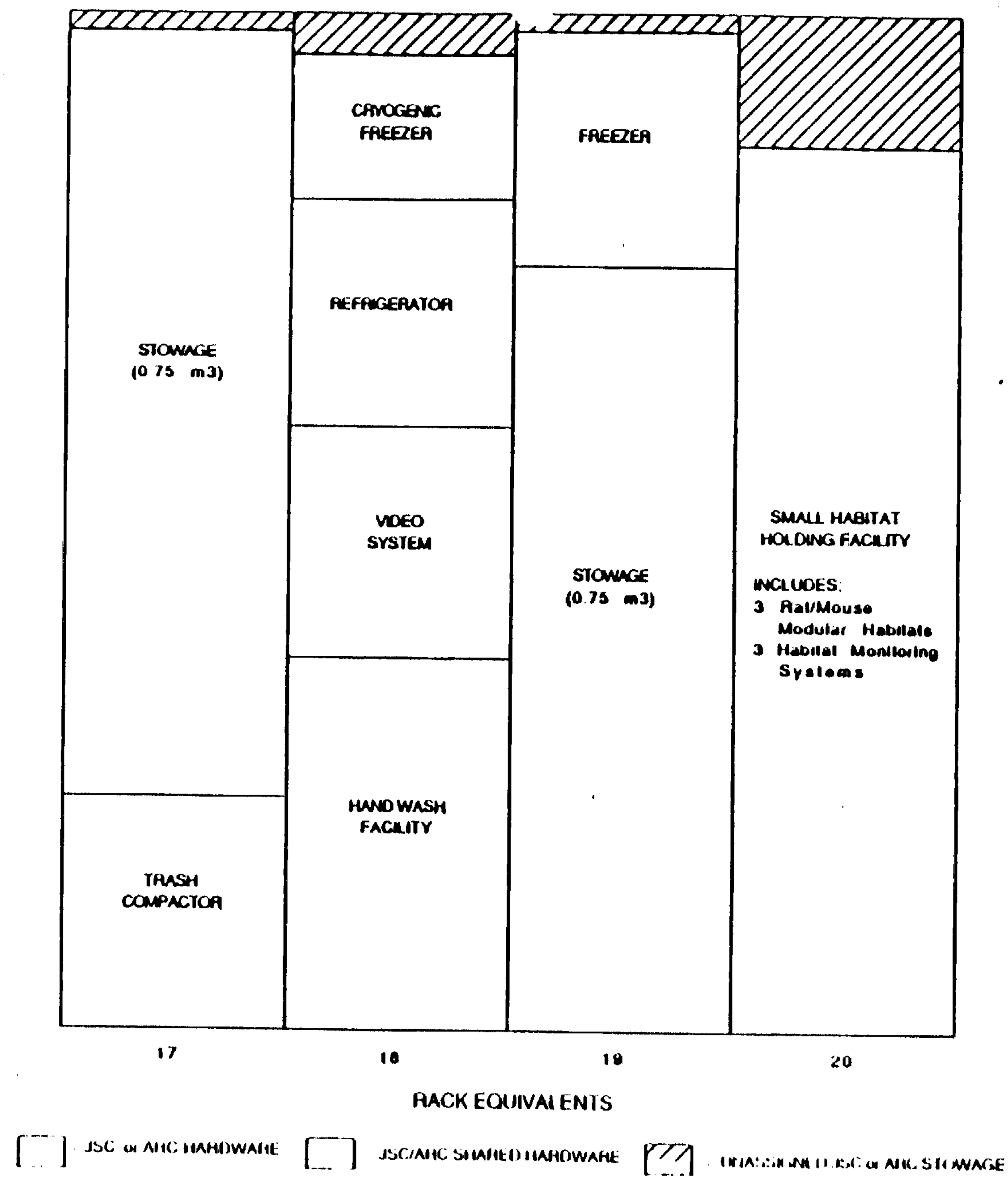

Figure LSRF-1. Rack Layout (Continued)

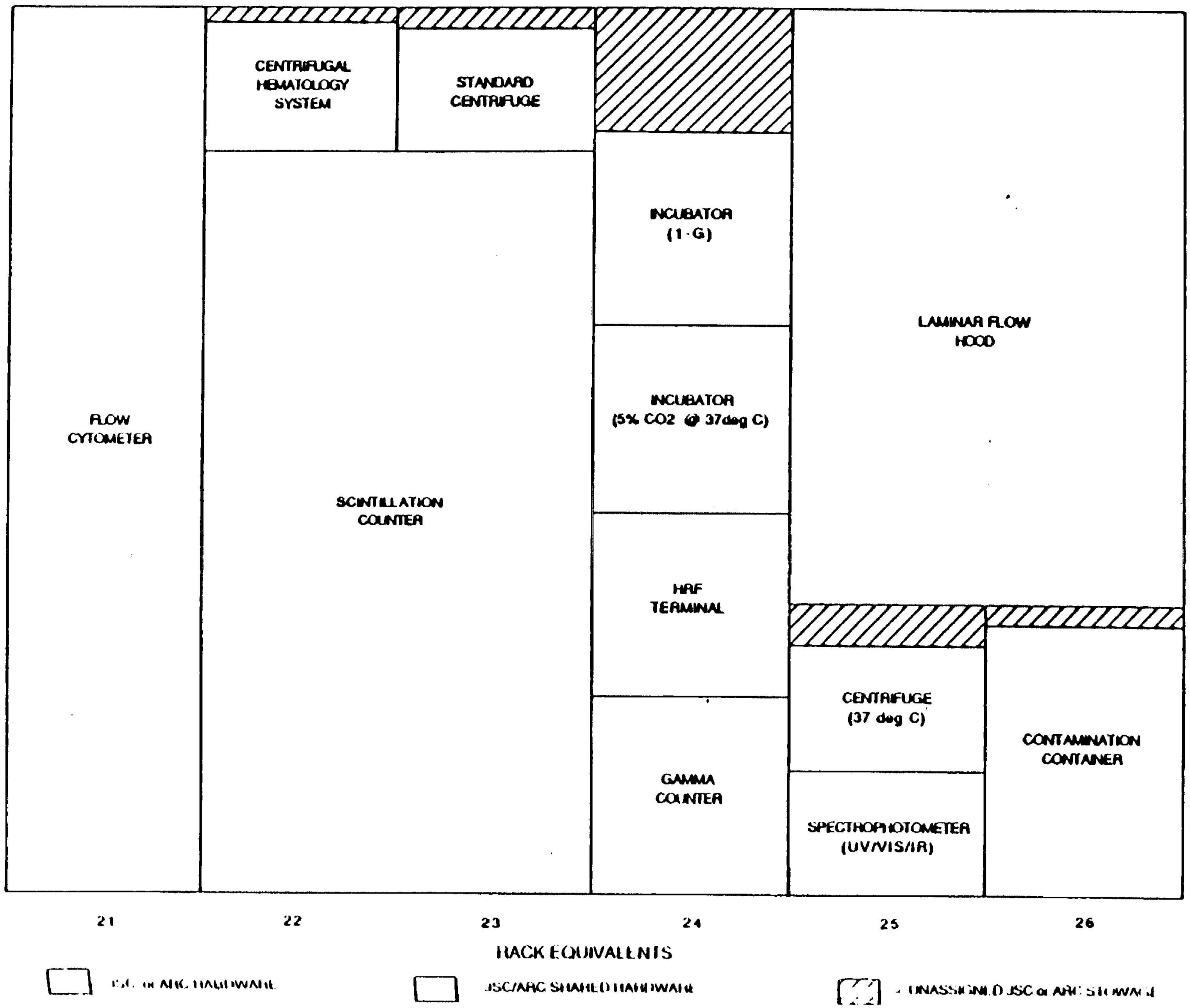

Figure LSRF-1. Rack Layout (Continued)

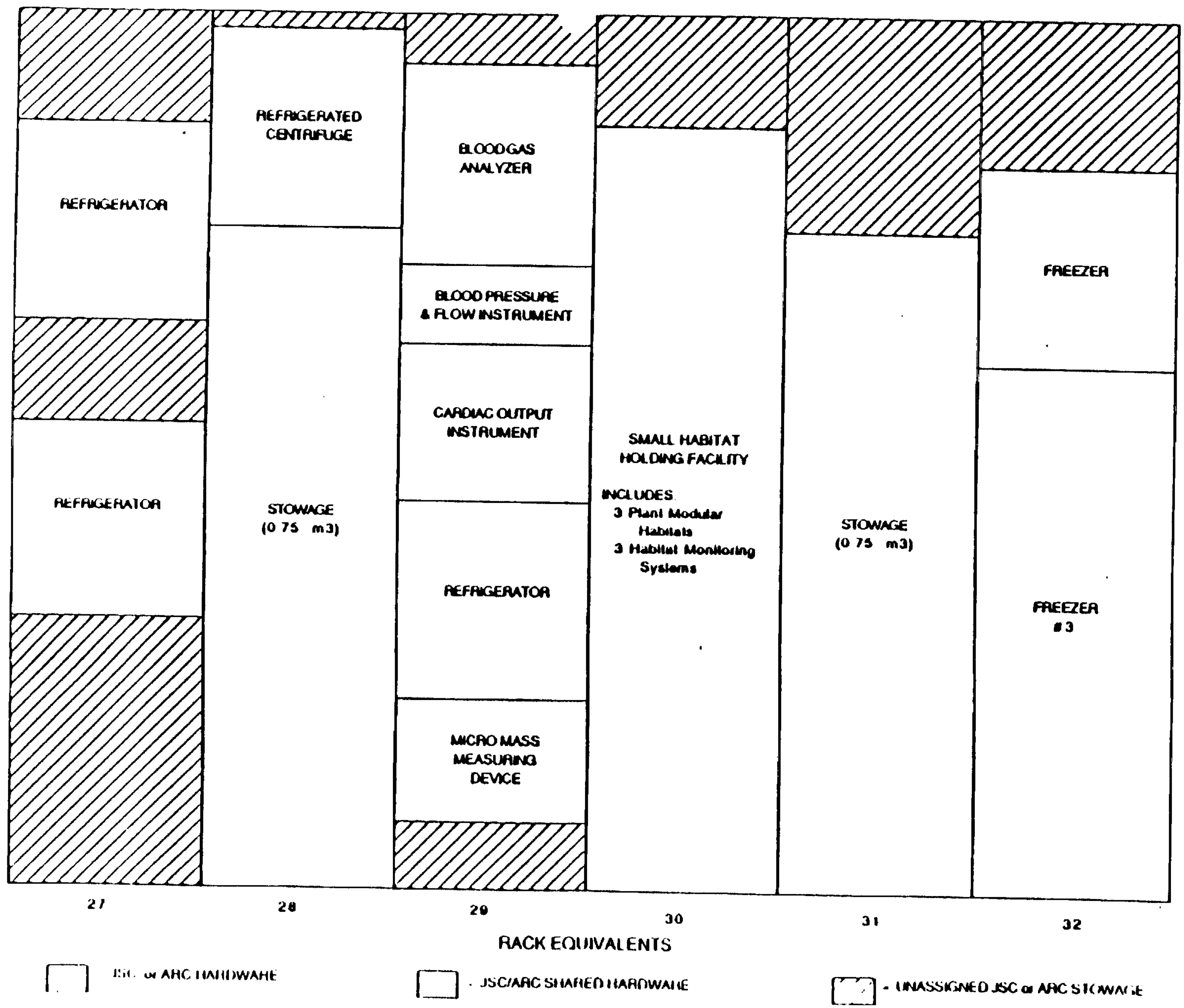

Figure LSRF-1. Rack Layout (Continued)

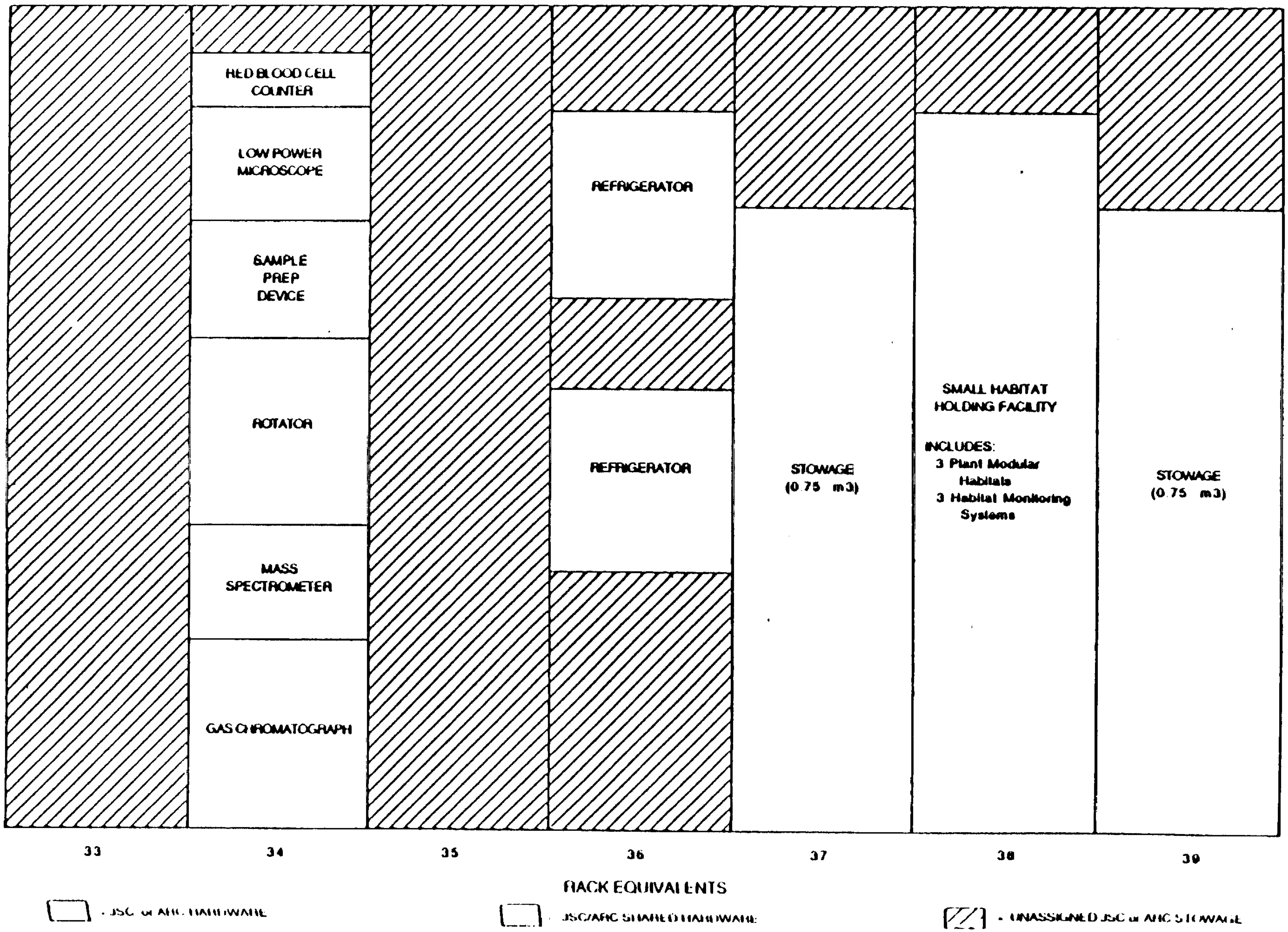

Figure LSRF-1. Rack Layout (Continued)

final complement of LSRF experiments/equipment will depend on the actual available STS manifest and available pressurized SS volume. The servicing requirements presented herein assume accommodation of the full desired RMOAD capability. Servicing requirements for a lesser capability can be developed from these data as needed.

2.2 LSRF Physical Characteristics

Mass:	11,650 kg (rack equipment)	
	3,000 kg (4.0 m centrifuge)	
Wet Mass:	N.A.	
Dimensions:	1.9 m x 1.1 m x 1.0	Equipment double rack
	2.4 m x 4.0 m (dia)	4.0 m centrifuge
Envelope:	39 m^3	Racks
	31 m^3	4.0 m centrifuge

2.3 LSRF Moving Parts and Special Features

Among the over seventy experiments planned for the LSRF, many contain moving parts and special features. Examples include: the rack-mounted 1.8 m and separate 4.0 m centrifuges; the exercise equipment; the presence of rodents, primates, and plants and their support; refrigerators and freezers; a workbench; and hazardous/contaminated materials.

2.4 LSRF Consumables

LSRF consumables will depend on the specific experiments which are actually flown. However, two general classes of consumables are considered for the purpose of developing LSRF requirements:

(1) Food and water for the animal/plant subjects; and

(2) Other materials, generally stowed, which are expended as part of all experiments, such as:

a. Blood handling disposables

b. Cell handling expendables

c. Film

d. Video tapes

e. Filters

f. Other experiment support consumables

g. Agar plates and strips
h. Assay chemicals
i. Special kits
j. Working materials
k. Cryogens

3.0 LSRF SERVICING INFORMATION

3.1 General Description for Servicing of LSRF

Servicing activities include consumables resupply, expendables removal, and rack equipment changeout (reconfiguration). All servicing will be performed as IVA here assumed to be provided by SS, (except for those supporting tasks, which involve transferring required servicing materials transported in unpressurized configuration in the SS logistics carrier). All continuous servicing to be done in the LSRF will be in support of the BRP experiments in maintaining the animal subjects.

During the inital currently planned six-year phased build-up of the LSRF capability, LSRF equipment racks will be installed, (i.e., LSRF will be "assembled") at the rate of approximately 5 m^3 per flight for the first four and last four of outfitting flights, and the 4.0 m centrifuge will arrive on the ninth outfitting flight. This will complete the capability. Sustained servicing after this period will consist of resupply of consumables, removal of expendables, and changing out racks and/or rack equipment for upgrade or failure purposes with every 90 day logistics flight. Note that the "actual" service occurs on a continuous basis since the berthed space station Logistics Module represents an available depot which stores items to be consumed and waste to be returned.

3.2 LSRF Background

The LSRF experiments and equipment represent a mix of elements to be newly developed, and some hardware already flown on Spacelab or to be flown prior to the SS.

3.3 Primary Role of Space Station in Servicing LSRF

The LSRF is part of the SS configuration. LSRF will be resupplied with consumables and undergo equipment changeout on a quarterly basis from the SS Logistics Module.

3.4 Primary Space Station Facilities Required for Servicing LSRF

Access to Logistics Module and servicing workbench (if required); interface to SS utilities; and storage of consumables and waste.

3.5 Space Station Personnel required for Servicing LSRF

Based on data contained in the RMOAD (see Bibliography), the crew will be required to provide approximately 35 hours per week to provide consumables resupply, waste removal for the BRP (animal) experiments, and equipment changeout for all experiments and approximately seven hours per week in servicing the 4.0 m centrifuge. Training will be required in servicing with emphasis on the plant and animal holding facilities.

3.6 Servicing Precautions for LSRF

During servicing, bioisolation must be maintained and cross-contamination avoided, particularly between crew and non-crew subjects.

3.7 Orbital Maneuvering Vehicle (OMV) Flight Profile Support of LSRF

LSRF resides within the SS's permanently attached pressurized modules and resources nodes, and as such, requires no OMV support.

4.0 LSRF SERVICING SAFETY CONSIDERATIONS

4.1 LSRF Hazardous Systems and Components

Hazards within the LSRF depend on the complement of experiments and hardware actually flown. A summary of the hazards which may be encountered follows:

(1) Centrifuges (1.8 m and 4.0 m)

(2) Pressurized gases

(3) Human/animal cross-contamination
(4) Cryogens
(5) Hazardous reagents
(6) Tracer radioisotapes
(7) Syringes/glassware
(8) Non-contained animal food, water, and waste
(9) All air and water filters

4.2 LSRF Servicing Safety Precautions

If the laboratory is occupied by a single person, constant video/radio contact with others in the Space Station shall be maintained.

5.0 LSRF SERVICING INTERFACES AND RESOURCE REQUIREMENTS

5.1 LSRF Crew Convenience Features

Video cameras, monitors, and VCRs will be provided for experiment/operation monitoring, and maximum use of rack slides and stowage compartments will be included. All servicing of equipment will be readily performed via front-panel equipment access. On-board crew activities will require voice activated wireless headsets to allow for hands-free, unencumbered communications between crew members in remote on-board locations and other personnel. Design interfaces for easy intergration/deintegration of equipment (plug-in, latch-down simplicity) will be provided; interior attachments for mounting standard size laboratory equipment will be provided; and experiment equipment attachment/disconnect shall minimize special tooling required.

5.2 MMPF Mechanical Interfaces

Hatches must allow passage of an equipment set measuring 1.0 m deep by 1.1 m wide by 1.9 m high (which is one standard double rack). Specific mechanical interfaces between LSRF equipment (racks, stowed equipment, and stand alone equipment) and the pressurized modules is not yet defined.

5.3 LSRF Umbilical Interfaces

All power, data, fluid, and life support utilities will be provided as part of the pressurized module interface. Specific needs will depend on the actual complement of experiments flown. Expected utilities are as follows:

a. Power
   - (1) Operating: 9.5 Kw average
   - (2) Servicing: To be performed within available operating power limits
   - (3) Stablilized AC and DC power is required

b. Data

   Requirements for servicing activities are TBD. LSRF's operational requirements are:
   - (1) Digital data: 400 kbps
   - (2) Video data: 14 Mbps (single channel)
   - (3) Voice data to ground capability

c. Fluid

   Gases, water, cooling fluids

5.4 LSRF RF Communication Interface

LSRF will employ SS facilities for all RF communications, except for experiment specific RF, such as for the biotelemetry system (BTS).

5.5 LSRF Thermal Interface

The fully operational LSRF thermal load (including hardware and metabolic loads) is 9.6 Kw. SS will provide air and water for cooling, as well as O_2 and CO_2 removal for animals. The atmosphere within the pressurized module is a man-habitable environment with sufficient air circulation flow capacity to accommodate up to 6 crew at any time (20 to 25 degrees C, 55 $\pm$ 15% relative humidity, a dew point no less than 6 degrees Celsius, 14.7 +/- 0.2 psi, and less than 23% O_2 for flammability reasons).

6.0 LSRF SERVICING ENVIRONMENT

6.1 LSRF Pointing/Orientation Constraints

a. Exposure to Light

Not applicable; LSRF is not light sensitive.

b. Thermal Control

Not applicable; LSRF has no pointing related ambient heat restrictions.

6.2 LSRF Contamination Concerns

Attention to bioisolation procedures is required to prevent biological cross-contamination. In addition, attention to cabin air trace contamination is required to avoid adverse affects on specimens.

6.3. LSRF Radiation Concerns

Radiation is of concern to LSRF. Radiation levels should be monitored to determine effects to LSRF investigations and crew.

7.0 LSRF SERVICING ACCOMMODATIONS

7.1 LSRF Equipment Access

LSRF is designed for on-orbit servicing with a high level of equipment accessibility. Most equipment is rack mounted with slides. Some equipment may require servicing in the servicing workbench.

7.2 LSRF Modularity

LSRF experiment equipment is considered modular. Facilities will be designed for on-orbit replacement, and will have standardized mechanical, electrical, thermal, gaseous, and vacuum interfaces.

7.3 LSRF Automated Servicing

The degree of automation varies among experiments. Many experiments are fully automated once the experiment has started. Others require monitoring as the experiment progresses. Setup,

preparation of samples, and cleanup are not automated processes. Automation involving robotics is TBD.

7.4 LSRF Servicing in the Space Station Pressurized Modules

LSRF servicing will be conducted primarily through IVA within the pressurized laboratory and resource node modules. Those EVA activities required to transfer servicing materials needed by LSRF but transported in unpressurized configuration within the SS logistics carriers are assumed to be provide by SS.

8.0 LSRF SERVICING MATERIALS CHECKLIST

SERVICING EQUIPMENT	REQUIRED	SS PROVIDED	COMMENTS	REF. SECTION
SI(s)*	YES	NO	HUMAN SUBJECTS AND ANIMAL AND PLANT SPECIMENS	9.0
ORU(s)	YES	NO	EXPERIMENTAL RACK-MOUNTED EQUIPMENT	9.0
FLIGHT SUPPORT EQUIPMENT	YES	YES	INSTALLATION, MAINTENANCE, REPAIR AND HOUSEKEEPING EQUIPMENT	10.0
MISCELLANEOUS SERVICE EQUIPMENT	YES	YES	TEST/CHECKOUT EQUIP, WASTE MANAGE-MENT EQUIP, VACUUM VENT SUPPORT EQUIP, ET AL.	10.0
SERVICING EQUIPMENT CARRIER(S)	YES	YES	LOGISTICS MODULE	12.0
SERVICING CONSUMABLES				
PROPELLANT(S)	NO	NO		11.0
CONTAINER(S)	NO	NO		11.0
CRYOGEN(S)	YES	NO	REFRIGERATOR(S), FREEZER(S)	11.0
CONTAINER(S)	YES	YES		11.0

* For the LSRF, the "scientific instruments" (SIs) consist of the human subjects and animal and plant specimens.

SERVICING EQUIPMENT	REQUIRED	SS PROVIDED	COMMENTS	REF. SECTION
LIQUID(S)	YES	YES	POTABLE WATER ETC.	11.0
CONTAINER(S)	YES	YES		11.0
GASES	YES	YES		11.0
CONTAINER(S)	YES	YES		11.0
OTHER(S)	YES	NO	SOLIDS (FOOD, WASTE, ETC)	11.0
CONTAINER(S)	YES	YES		11.0
SERVICING CONSUMABLES CARRIERS(S)	YES	YES	LOGISTICS MODULE	12.0

9.0 LSRF ORBITAL REPLACEABLE UNITS (ORUs)

9.1 Servicing of LSRF ORUs

a. LSRF SIs

The LSRF "Scientific Instruments" (SIs) consist of the human subjects (crew members) and animal and plant specimens used for the biomedical and biological research experiments. The crew members are provided by SS. The animal and plant specimen are contained in modular habitats which, for the present purposes, are treated as ORUs.

b. LSRF ORUs

LSRF ORUs consist of all experimental rack-mounted equipment. Servicing of these ORUs consists primarily of equipment change-out every 90 days due to failure, equipment upgrade, or experiment change. At the present time approximately 140 separate pieces of rack-mounted equipment are considered ORU candidates, and their names, volume, mass, power, and dimensions are listed in Table LSRF-1. In addition to the LSRF ORUs, a large number and variety of stowed equipment and consumables will be stored in the racks in support of the experiments. Table LSRF - 2 provides a list of representative items. The list is not a complete representation of stowage required for the full LSRF capability since the actual items will depend on the experiments flown. The RMOAD (see Bibliography), from which Table LSRF-2 is taken, provides additional definition and characterization of stowed equipment for the full LSRF capability.

9.2 LSRF ORU Physical Characteristics

The volume, mass, power, and dimensions of each of the LSRF ORUs are listed in Table LSRF-1.

9.3 LSRF ORU Storage Requirements

It is currently assumed that approximately 10% of the rack-mounted ORUs will fail each quarter and approximately 2.5% will require change-out for other than failure purposes, which

TABLE LSRF-1. RACK MOUNTED EQUIPMENT

			PAYLOAD TOTALS			ITEM CHARACTERISTICS					
	EQUIPMENT NAME	QTY Reqd	VOL cu m	MASS kg	POWER watts	DEPTH m	WIDTH m	HEIGHT m	MASS kg	POWER watts	REMARKS
...	....	......	....	....	....	......	......	......	....	......	....
1	Biorack Radiation Dosimeter	1	0.008	5.00	0	0.200	0.200	0.200	5.00		
2	Cage Cleaning System	1	0.320	100.00	500	0.800	0.500	0.800	100.00	500	
3	Centrifuge -- 1-G Control (6 ft dia)	1	4.500	1000.00	200	1.442	1.442	1.442	1000.00	200	Power-1KW peak @ startup
4	Data System	1	0.320	40.00	200	0.800	0.500	0.800	40.00	200	
5	Densitometer, Bone	1	0.257	136.08	300	0.599	0.483	0.889	136.08	300	
6	Display, Video Monitor	1	0.029	6.80	50	0.660	0.483	0.090	6.80	50	
7	Dosimeter, Passive, Operator	1	0.090	5.00	0	0.600	0.500	0.300	5.00	0	
8	Dynamic Environ Meas. System	1	0.075	40.00	20	0.500	0.500	0.300	40.00	20	
9	Expmt Control and Data Interface	1	0.091	11.34	120	0.610	0.483	0.310	11.34	120	
10	Freeze Dryer	1	0.067	19.34	140	0.483	0.305	0.457	19.34	140	
11	Freezer #1	1	0.365	19.34	200	0.610	0.460	1.331	19.34	200	
12	Habitat Holding Facility, Small (Rodent)	1	0.754	150.00	250	0.910	0.910	0.910	150.00	250	
13	Habitat Monitoring System (Rodent)	3	0.000	60.00	75	0.660	0.406	0.356	20.00	25	Included in Modular Habitat
14	Habitat Monitoring System (Rodent)	3	0.000	60.00	75	0.660	0.406	0.356	20.00	25	Included in Modular Habitat
15	Incubator	1	0.142	27.22	100	0.632	0.483	0.464	27.22	100	
16	Inflight Digitizing System	1	0.390	35.00	500	0.890	0.890	0.492	35.00	500	
17	Ion Selective Chromotograph	1	0.024	12.69	200	0.495	0.146	0.330	12.69	200	
18	Isokinetic Measurement Device	1	0.017	7.98	0	0.305	0.254	0.222	7.98	0	
19	Life Support Kit, Med Emergency	1	0.754	13.61	100	0.910	0.910	0.910	13.61	100	
20	Mass Meas. Device, Small	1	0.075	15.00	15	0.500	0.500	0.300	15.00	15	
21	Modular Habitat (Rat/Mouse - 0.1 cu m)	3	0.000	90.00	150	0.660	0.406	0.356	30.00	50	Included in Holding Facility
22	Modular Habitat (Rat/Mouse - 0.1 cu m)	3	0.286	90.00	150	0.660	0.406	0.356	30.00	50	
23	Multi purpose work bench	1	1.920	350.00	500	0.800	1.000	2.400	350.00	500	
24	Reader T L D	1	0.085	15.42	150	0.508	0.254	0.659	15.42	150	
25	Recorder, Doppler	1	0.137	9.53	50	0.508	0.483	0.559	9.53	50	
26	Recorder, Video	1	0.037	16.42	75	0.508	0.483	0.152	15.42	75	
27	Refrigerator (4°C)	1	0.171	34.93	200	0.574	0.424	0.701	34.93	200	
28	SCR Multichannel	1	0.090	30.00	150	0.600	0.500	0.300	30.00	150	
29	Terminal, Computer	1	0.112	9.07	100	0.508	0.483	0.457	9.07	100	
30	Video System	4	0.600	180.00	600	0.600	0.500	0.600	45.00	150	
31											
32	TOTALS		14.059	2588.77	5170						
33											Vol includes 20% for packing mtls
34											

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TABLE LSRF-1. RACK MOUNTED EQUIPMENT (CONTINUED)

			PAYLOAD TOTALS			ITEM CHARACTERISTICS					
	EQUIPMENT NAME	QTY Reqd	VOL cu m	MASS kg	POWER watts	DEPTH m	WIDTH m	HEIGHT m	MASS kg	POWER watts	REMARKS
1	Bag-In-box	1	0.090	15.88	0	0.610	0.425	0.349	15.88	0	
2	Electronics Control Assembly	1	0.045	15.88	80	0.400	0.425	0.267	15.88	80	
3	Ergometer, Bicycle	1	0.120	13.61	10	0.400	0.500	0.599	13.61	10	
4	Exercise Device, Anaerobic	1	0.165	21.46	105	0.762	0.610	0.356	21.46	105	
5	Flowmeter, Cardiopul Analyzer	1	0.268	42.00	9	0.584	0.483	0.950	42.00	9	
6	Freezer #2	1	0.365	19.34	200	0.610	0.450	1.331	19.34	200	
7	Freezer (-70 deg C)	1	0.150	100.00	300	0.600	0.500	0.500	100.00	300	
8	Freezer, Cryogenic (-196°C)	1	0.090	20.00	0	0.600	0.500	0.300	20.00	0	
9	Gas Analyzer/Mass Spec	1	0.100	34.93	50	0.584	0.483	0.356	34.93	50	
10	Gas Cylinder Assembly	1	0.092	42.00	0	0.610	0.425	0.356	42.00	0	
11	Habitat Holding Facility, Small (Rodent)	1	0.754	150.00	250	0.910	0.910	0.910	150.00	250	
12	Habitat Monitoring System (Rodent)	9	0.000	180.00	225	0.660	0.406	0.356	20.00	25	Included in Modular Habitat
13	Habitat Monitoring System (Rodent)	3	0.000	60.00	75	0.660	0.406	0.356	20.00	25	Included in Modular Habitat
14	Hand Wash Facility	1	0.320	100.00	375	0.800	0.500	0.800	100.00	375	
15	Imaging System, Ultrasound	1	0.179	90.72	600	0.609	0.483	0.609	90.72	600	
16	L B N P Device	1	0.293	19.05	55	0.762	0.483	0.795	19.05	65	
17	Mass Meas Device Body	1	0.067	34.02	15	1.029	0.083	0.795	34.02	16	
18	Modular Habitat (Rat/Mouse - 0.1 cu m)	3	0.000	90.00	150	0.660	0.406	0.356	30.00	50	Included in Holding Facility
19	Modular Habitat (Rat/Mouse - 0.1 cu m)	9	0.859	270.00	300	0.660	0.406	0.356	30.00	50	
20	Monitor, Heart Rate	1	0.000	0.95	10	0.102	0.051	0.025	0.95	10	
21	Oscilloscope	1	0.030	14.00	100	0.300	0.500	0.200	14.00	100	
22	Refrigerator	1	0.150	100.00	200	0.600	0.500	0.500	100.00	200	
23	Rowing Machine	1	0.220	17.24	0	1.219	0.711	0.254	17.24	0	
24	Trash Compactor	1	0.200	30.00	250	0.800	0.500	0.500	30.00	250	
25	Treadmill	1	0.311	11.79	25	1.219	0.559	0.457	11.79	25	
26											
27	TOTALS		5.844	1492.87	3384						
28											Vol includes 20% for packing mils
29											

TABLE LSRF-1. RACK MOUNTED EQUIPMENT (CONTINUED)

			PAYLOAD TOTALS			ITEM CHARACTERISTICS					
		QTY	VOL	MASS	POWER	DEPTH	WIDTH	HEIGHT	MASS	POWER	
	EQUIPMENT NAME	Reqd	cu m	kg	watts	m	m	m	kg	watts	REMARKS
1	Biotelemetry System	1	0.030	30.00	50	0.300	0.500	0.200	30.00	50	
2	Blood Gas Analyzer	1	0.125	45.00	250	0.500	0.500	0.500	45.00	250	
3	Cardiac Output Instrumentation (animal)	1	0.080	10.00	75	0.400	0.500	0.400	10.00	75	
4	Centrifugal Hematology System	1	0.016	22.68	200	0.229	0.229	0.311	22.68	200	
5	Centrifuge, 37 deg C	1	0.090	30.00	450	0.600	0.500	0.300	30.00	450	
6	Centrifuge, Refrigerated	1	0.200	40.00	450	0.800	0.500	0.500	40.00	450	
7	Centrifuge, Standard Lab	1	0.090	30.00	350	0.600	0.500	0.300	30.00	350	
8	Container, Contamination	1	0.243	54.43	0	0.762	0.483	0.660	54.43	0	
9	Counter, Scintillation	1	1.255	181.44	500	1.829	0.711	0.965	181.44	500	
10	Flow Cytometer	1	1.000	136.08	500	0.914	0.483	2.266	136.08	500	
11	Freezer #3	1	0.365	19.34	200	0.610	0.450	1.331	19.34	200	
12	Freezer (-70 deg C)	1	0.150	100.00	300	0.600	0.500	0.500	100.00	300	
13	Gamma Counter	1	0.173	183.00	10	0.686	0.495	0.508	183.00	10	
14	Habitat Holding Facility, Large (Rhesus)	1	0.754	150.00	250	0.910	0.910	0.910	150.00	250	
15	Habitat Holding Facility, Small (Plant)	1	0.754	150.00	250	0.910	0.910	0.910	150.00	250	
16	Habitat Monitoring System (Plant)	3	0.000	60.00	75	0.660	0.406	0.356	20.00	25	Included in Modular Habitat
17	Habitat monitoring system (Rhesus)	1	0.000	20.00	25	0.406	0.355	0.152	20.00	25	Included in Modular Habitat
18	Incubator (1g)	1	0.142	27.22	100	0.632	0.483	0.464	27.22	100	
19	Incubator (5% CO2@37°C)	1	0.142	27.22	100	0.632	0.483	0.464	27.22	100	
20	Laminar Flow Hood	1	0.690	77.00	500	0.724	1.470	0.648	77.00	500	
21	Mass Meas Device, Micro	1	0.075	15.00	15	0.500	0.500	0.300	15.00	15	
22	Modular Habitat (Plant)	3	0.000	120.00	750	0.660	0.406	0.356	40.00	250	Included in Holding Facility
23	Modular Habitat (Rhesus)	1	0.000	150.00	250	0.660	0.406	0.712	150.00	250	Included in Holding Facility
24	Refrigerator	3 ~~1~~	0.150	100.00	200	0.600	0.500	0.500	100.00	200	
25	Spectrophotometer (Visual, UV, IR)	1	0.099	40.00	300	0.660	0.500	0.300	40.00	300	
26											
27	TOTALS		7.946	1818.41	6150						Vol includes 20% for packing matls
28											
29											

TABLE LSRF-1. RACK MOUNTED EQUIPMENT (CONTINUED)

			PAYLOAD TOTALS			ITEM CHARACTERISTICS					
	EQUIPMENT NAME	QTY Reqd	VOL cu m	MASS kg	POWER watts	DEPTH m	WIDTH m	HEIGHT m	MASS kg	POWER watts	REMARKS
1	Counter, Red Blood Cell	1	0.034	45.36	50	0.537	0.483	0.133	45.36	50	
2	Expmt Control and Data Interface	1	0.091	11.34	120	0.610	0.483	0.310	11.34	120	
3	Gas Chromatograph	1	0.200	25.00	100	0.800	0.500	0.500	25.00	100	
4	Habitat Holding Facility, Large (Rhesus)	1	0.754	150.00	250	0.910	0.910	0.910	150.00	250	
5	Habitat Monitoring System (Plant)	2	0.000	40.00	50	0.660	0.406	0.356	20.00	25	Included in Modular Habitat
6	Habitat monitoring system (Rhesus)	1	0.000	20.00	25	0.406	0.355	0.152	20.00	25	Included in Modular Habitat
7	Habitat monitoring system (Rhesus)	1	0.000	20.00	25	0.406	0.355	0.152	20.00	25	Included in Modular Habitat
8	HRF Terminal	1	0.112	22.68	15	0.508	0.483	0.457	22.68	15	
9	Mass Spectrometer	1	0.075	40.00	150	0.500	0.500	0.300	40.00	150	
10	Microscope, Low Power	1	0.013	7.26	100	0.229	0.190	0.305	7.26	100	
11	Modular Habitat (Plant)	2	0.191	80.00	500	0.660	0.406	0.356	40.00	250	For Centrifuge
12	Modular Habitat (Rhesus)	1	0.191	150.00	250	0.660	0.406	0.712	150.00	250	
13	Modular Habitat (Rhesus)	1	0.000	150.00	250	0.660	0.406	0.712	150.00	250	Included in Holding Facility
14	Rotator	1	0.125	40.82	220	0.508	0.483	0.508	40.82	220	
15	Sample Prep Dev, Fluid X-fer	1	0.179	11.33	150	0.609	0.483	0.609	11.33	150	
16											
17	TOTALS		2.358	813.79	2255						Vol includes 20% for packing mtls.
18											
19											

TABLE LSRF-1. RACK MOUNTED EQUIPMENT (CONTINUED)

			PAYLOAD TOTALS			ITEM CHARACTERISTICS					
		QTY	VOL	MASS	POWER	DEPTH	WIDTH	HEIGHT	MASS	POWER	
	EQUIPMENT NAME	Reqd	cu m	kg	watts	m	m	m	kg	watts	REMARKS
1	Centrifuge (4 meter dia)	1	31.400	3000.00	600	2.5m wide x 4.0m dia			3000.00	600	Power - 1.5KW peak @ startup
2	Centrifuge (4 meter dia) Controls	1	1.500	0.00	0						Mass & Pwr included in 4M centige
3	Refridgerator	4	0.684	139.72	800	0.574	0.424	0.703	34.93	200	
4											
5	TOTALS		40.301	3139.72	1300						Vol includes 20% for packing matls
6											
7											

TABLE LSRF-2. STOWED EQUIPMENT

			PAYLOAD TOTALS			ITEM CHARACTERISTICS					
	EQUIPMENT NAME	QTY Reqd	VOL cu m	MASS kg	POWER watts	DEPTH m	WIDTH m	HEIGHT m	MASS kg	POWER watts	REMARKS
1	Agar Plates	1116	0.103	50.62	0	0.076	0.076	0.016	0.05	0	
2	Agar Strips	754	0.034	398.87	0	0.025	0.305	0.006	0.53	0	
3	Blood Collection Disposables	2160	0.027	122.45	0	0.013	0.013	0.076	0.06	0	
4	Blood Collection Reusables	1	0.028	1.36	0	0.305	0.305	0.305	1.36	0	
5	Camera, 35 mm	1	0.010	1.50	0	0.200	0.200	0.250	1.50	0	
6	Camera, Polaroid	1	0.002	1.00	0	0.100	0.150	0.150	1.00	0	
7	Cation Exchange Resin Kit	3	0.002	0.41	0	0.102	0.076	0.076	0.14	0	
8	Cell Culture Expendables	24	0.079	41.76	0	0.127	0.254	0.102	1.74	0	
9	Cell Handling Accessories	102	0.046	69.40	0	0.152	0.102	0.029	0.68	0	
10	Computer, Stimulus Control	1	0.033	14.97	80	0.424	0.434	0.178	14.97	80	
11	Cr51 Tagging Kit/Shield	2	0.100	0.11	0	1.408	0.279	0.254	0.05	0	
12	Display, Venous Press Recorder	1	0.004	2.27	25	0.305	0.051	0.229	2.27	25	
13	Elisa Analysis Chemicals	3	0.002	0.00	0	0.076	0.254	0.052	0.00	0	
14	Elisa Reader	1	0.030	15.87	0	0.229	0.200	0.050	15.87	0	
15	Evans Blue Dye Injection Kit	144	0.028	11.61	0	0.051	0.051	0.076	0.08	0	
16	Film	5	0.125	10.00	0	0.500	0.500	0.100	2.00	0	
17	Filter Kit, Millipore	1	0.028	0.23	0	0.305	0.305	0.305	0.23	0	
18	Filters, Millipore	36	0.001	0.16	0	0.076	0.076	0.006	0.00	0	
19	Fixation Kit	1	0.120	20.00	0	0.600	0.500	0.400	20.00	0	
20	Food (ea Rat/90 day)	48	0.240	144.00	0	0.173	0.170	0.170	3.00	0	
21	Food (ea Rhesus/90 day)	2	0.100	50.00	0	0.232	0.464	0.464	25.00	0	
22	Helmet Assembly	1	0.046	5.23	20	0.470	0.310	0.318	5.23	20	
23	Helmet Interface Box	1	0.023	7.96	30	0.457	0.330	0.152	7.96	30	
24	Helmet Restraint	1	0.000	0.23	0	0.076	0.076	0.025	0.23	0	
25	Heparin Lock Kit	140	0.013	9.44	0	0.203	0.076	0.006	0.07	0	
26	Iodine Isotope Kit/Shield	6	0.642	1.00	0	0.455	0.483	0.455	0.17	0	
27	Isotope Kit, Fe59/Shield	4	0.428	1.00	0	0.455	0.483	0.455	0.25	0	
28	Loops, Sterile	754	0.074	12.22	0	0.203	0.076	0.006	0.02	0	
29	Mitogen Kit	24	0.001	12.48	0	0.051	0.102	0.192	0.52	0	
30	Nutrient (All Plants/90 Days)	1	0.001	0.50	0	0.100	0.100	0.100	0.50	0	
31	Phycol & P B S Consumables Kit	102	0.161	106.42	0	0.152	0.102	0.102	1.04	0	
32	Plant Care Kit	1	0.010	10.00	0	0.215	0.215	0.215	10.00	0	
33	Plant Care Kit	1	0.010	10.00	0	0.215	0.215	0.215	10.00	0	
34	Plant Harvesting Kit	1	0.016	5.00	0	0.400	0.200	0.200	5.00	0	
35	Plant Harvesting Kit	1	0.016	5.00	0	0.400	0.200	0.200	5.00	0	
36	Radioisotopes/ Shielding	1	0.107	1.00	0	0.455	0.483	0.455	1.00	0	
37	Reagent Kit, Red Cell Mass	4	0.001	0.36	0	0.076	0.051	0.051	0.09	0	
38	Reticulocyte Smear Kit	4	0.001	0.36	0	0.076	0.076	0.013	0.09	0	
39	Rodent Veterinary Kit	1	0.016	5.00	0	0.400	0.200	0.200	5.00	0	
40	Sample Swabs and Sample Tubes	1080	0.053	24.50	0	0.025	0.025	0.076	0.02	0	
41	Seed Planting Kit	1	0.016	5.00	150	0.400	0.200	0.200	5.00	150	
42	Seed Planting Kit	1	0.016	5.00	150	0.400	0.200	0.200	5.00	150	
43	Slide Prep Device, Chromosal	1	0.003	3.27	0	0.368	0.211	0.044	3.27	0	
44	Specimens (Plants)	20	0.001	4.00	0	0.010	0.010	0.010	0.20	0	Included in Holding Facility

TABLE LSRF-2. STOWED EQUIPMENT (CONTINUED)

			PAYLOAD TOTALS			ITEM CHARACTERISTICS					
		QTY	VOL	MASS	POWER	DEPTH	WIDTH	HEIGHT	MASS	POWER	
	EQUIPMENT NAME	Reqd	cu m	kg	watts	m	m	m	kg	watts	REMARKS
45	Specimens (Rhesus)	2	0.000	4.00	0				2.00	0	Included in Modular Habitat
46	Stowage (Expendables)	1	0.754	300.00	0	0.910	0.910	0.910	300.00	0	
47	Stowage (Expendables)	1	0.754	300.00	0	0.910	0.910	0.910	300.00	0	
48	Transducer, Venous Pressure	1	0.000	0.68	0	0.102	0.051	0.051	0.68	0	
49	Trypticase Soy Agar Strips	120	0.000	0.54	0	0.026	0.076	0.000	0.00	0	
50	Tubes, Blood Collection	2160	0.026	122.26	0	0.013	0.013	0.076	0.06	0	
51	Tubes, Blood Collection, Spares	108	0.001	6.11	0	0.013	0.013	0.076	0.06	0	
52	Venous Pressure Disposables	156	0.002	8.83	0	0.013	0.013	0.076	0.06	0	
53	Water (ea. Rat/90 day)	48	0.240	240.00	0	0.173	0.170	0.170	5.00	0	
54	Water (ea. Rhesus/90 day)	2	0.200	200.00	0	0.464	0.464	0.464	100.00	0	
55	Water for Plants (liters)	400	0.400	400.00	0	0.100	0.100	0.100	1.00	0	
56	Wipes, Dry	1	0.001	0.10	0	0.150	0.100	0.050	0.10	0	
57	Wipes, Wet	1	0.002	0.10	0	0.150	0.100	0.100	0.10	0	
58	Failed Hardware Replacements (10%)		3.872	1424.30							
59	Hardware For Changeout (2.5%)		0.968	356.10							
60											
61	TOTALS		12.021	4554.56	465						Vol includes 20% for packing mtls
62											
63											

represents a requirement to replace approximately 5.2 m^3 and 2125 kg of ORU equipment. Most ORUs require no power when stored on SS.

9.4 Other Environmental Requirements for LSRF ORUs

None

10.0 LSRF FLIGHT SUPPORT AND MISCELLANEOUS SERVICING EQUIPMENT

10.1 LSRF Flight Support Equipment (FSE)

The FSE for the LSRF consists of the equipment needed to install, repair, maintain, and provide general housekeeping for the facilities. It is assummed that SS will provide the LSRF FSE. The specific FSE required is currently under definition.

10.2 LSRF FSE Physical Characteristics

This equipment is Space Station provided.

10.3 LSRF FSE Storage Requirements

This equipment is Space Station provided and therefore is a Space Station responsibility.

10.4 Miscellaneous Servicing Equipment

The LSRF will also require: test and checkout equipment for SS and experiment-specific application; waste management equipment for use with bioisolation and wet, dry and radioactive waste; vacumm vent support equipment; and other miscellaneous servicing equipment not contained above. It is assumed that SS will provide all necessary miscellaneous servicing equipment. The specific equipment required is currently under definition.

11.0 LSRF SERVICING CONSUMABLES AND CONTAINERS

11.1 Description and Purpose

Consumables within the LSRF fall into two broad categories:

(1) Consumables required to maintain the animal and plant specimens, i.e., food and water; and

(2) Consumables expended during the course of running experiments and operating the hardware, i.e., kits, special reagents, cryogens, collection equipment, special cleaning materials, etc.

Section 11.2 provides specific data concerning candidate consumables.

11.2 Physical Characteristics

Table LSRF-2 includes the characteristics of consumables for the LSRF. The volume, mass, power, and dimensions shown represent the quantity of consumables expended in a 90 day period.

11.3 Storage Requirements

All consumables will be stowed within the racks of the LSRF. The volume, mass, and power requirements are as listed in Table LSRF - 2.

12.0 CARRIERS FOR LSRF SERVICING MATERIALS

12.1 Description and Purpose of Carriers

LSRF ORUs and consumables will be transported to SS via the STS in the Logistics Module. Because of the presence of animal and plant specimens, pressurized transport will be required. Containers for specific LSRF items within the Logistics Module are TBD.

12.2 STS and SS Carrier Interfaces

The STS will transport the Logistics Module via sill and keel fittings, and SS will provide a docking port for the Logistics Module at a resource node or pressurized module hatch. The transport of specimens in the Logistics Module requires that it be pressurized.

12.3 Servicing Materials/Carrier Interface

The specific interface between individual LSRF items within the Logistics Module and the interior of the logistics module is TBD.

13.0 LSRF ORBITAL SERVICING ACTIVITIES TIME ESTIMATES

13.1 Mission Servicing Ground Rules and Constraints

The LSRF project has defined consumables servicing to consist exclusively of animal maintenance in support of BRP experiments with minor contributions from miscellaneous minor activities, (such as battery replacement for all equipment). Any consumables activities associated with the preparation, conduct, and post-conduct of human experiments is considered part of the experiment protocol, and hence counted as "operational" time only. Contingency servicing requirments are not addressed. All equipment, consumables, and expended materials not currently in use are assumed to be stowed in the LSRF racks and possibly the logistics module. The majority of servicing is performed via IVA. Some EVA, which is TBD, may be required to transfer needed servicing materials into and out of the pressurized modules from unpressurized carriers. This, however, is assumed to be a SS service as part of normal logistics carrier operations. Table LSRF - 3 summarizes a representative logistics flight supply/return mission (taken from the RMOAD), which is used as the basis for data presented in the following sections.

13.2 Preparatory Servicing Time Estimates

No activities are identified. (Unloading of the Logistics Module from the Orbiter is considered Space Station operations).

13.3 Principal Servicing Time Estimates

Three types of activities will be performed during LSRF's "principal" servicing: resupply of animal consumables and removal of waste on a continuous basis; changeout of rack-mounted equipment every 90 days to replace failed equipment and

TABLE LSRF-3. MATERIALS RESUPPLY

		PAYLOAD TOTALS				ITEM CHARACTERISTICS					
	EQUIPMENT NAME	QTY Reqd	VOL cu m	MASS kg	POWER watts	DEPTH m	WIDTH m	HEIGHT m	MASS kg	POWER watts	REMARKS
1	Agar Plates	1116	0.103	50.62	0	0.076	0.076	0.016	0.05	0	
2	Agar Strips	754	0.009	398.87	0	0.025	0.076	0.006	0.53	0	
3	Blood Collection Disposables	2160	0.027	122.45	0	0.013	0.013	0.076	0.06	0	
4	Blood Collection Reusables	1	0.028	1.36	0	0.305	0.305	0.305	1.36	0	
5	Cation Exchange Resin Kit	3	0.002	0.41	0	0.102	0.076	0.076	0.14	0	
6	Cell Culture Expendables	24	0.079	41.76	0	0.127	0.254	0.102	1.74	0	
7	Cell Handling Accessories	102	0.046	69.40	0	0.152	0.102	0.029	0.68	0	
8	Container (Rat Carcass)	43	0.048	19.35		0.073	0.076	0.203	0.45		
9	Elisa Analysis Chemicals	3	0.002	0.00	0	0.076	0.254	0.052	0.00	0	
10	Evans Blue Dye Injection Kit	144	0.028	11.61	0	0.051	0.051	0.076	0.08	0	
11	Film	5	0.125	10.00	0	0.500	0.500	0.100	2.00	0	
12	Filter Kit, Millipore	1	0.028	0.23	0	0.305	0.305	0.305	0.23	0	
13	Filters, Millipore	36	0.001	0.16	0	0.076	0.076	0.006	0.00	0	
14	Fixation Kit	6	0.720	120.00					20		
15	Food (ea Mouse/90 day)	100	0.000	54.40					0.544		In food tray
16	Food (ea Rat/90 day)	135	0.000	357.00					2.64444		In food tray
17	Food tray, Mouse	416	0.830	374.82					0.901		
18	Food tray, Rat	885	1.800	795.62					0.899		
19	Heparin Lock Kit	140	0.013	9.44	0	0.203	0.076	0.006	0.07	0	
20	Isotope Kit, Fe59/Shield	4	0.428	1.00	0	0.455	0.483	0.455	0.25	0	
21	Loops, Sterile	754	0.074	12.22	0	0.203	0.076	0.006	0.02	0	
22	Mitogen Kit	24	0.001	12.48	0	0.051	0.102	0.192	0.52	0	
23	Modular Habitat (Rat)	33	3.300	990.00					30		
24	Phycol & P B S Consumables Kit	102	0.161	106.42	0	0.152	0.102	0.102	1.04	0	
25	Radioisotopes/ Shielding	1	0.107	1.00	0	0.455	0.483	0.455	1.00	0	
26	Reagent Kit, Red Cell Mass	4	0.001	0.36	0	0.076	0.051	0.051	0.09	0	
27	Reticulocyte Smear Kit	4	0.001	0.36	0	0.076	0.076	0.013	0.09	0	
28	Sample Swabs and Sample Tubes	1080	0.053	24.50	0	0.025	0.025	0.076	0.02	0	
29	Slide Prep Device, Chromosal	1	0.003	3.27	0	0.368	0.211	0.044	3.27	0	
30	Specimens (Rats)	126	0.000	63.00					0.5		In Modular Habitat
31	Stowage (Expendables)	1	0.754	125.00					125		
32	Stowage (Expendables)	1	0.754	125.00					125		
33	Trypticase Soy Agar Strips	120	0.000	0.54	0	0.025	0.076	0.000	0.00	0	
34	Tubes, Blood Collection	2160	0.026	122.26	0	0.013	0.013	0.076	0.06	0	
35	Venous Pressure Disposables	156	0.002	8.83	0	0.013	0.013	0.076	0.06	0	
36	Video Tapes	60	0.110	15.00					0.25		
37	Waste Tray, Mouse	416	0.830	374.82					0.901		
38	Waste Tray, Rat	885	1.800	796.00					0.89943		
39	Water (ea Mouse/90 day)	100	0.040	43.50					0.435		
40	Water (ea Rat/90 day)	135	0.571	571.05					4.23		

TABLE LSRF-3. MATERIALS RESUPPLY (CONTINUED)

		PAYLOAD TOTALS				ITEM CHARACTERISTICS					
		QTY	VOL	MASS	POWER	DEPTH	WIDTH	HEIGHT	MASS	POWER	
	EQUIPMENT NAME	Reqd	cu m	kg	watts	m	m	m	kg	watts	REMARKS
41	Water for cage Washer (Liters)	205	0.210	205.00					1		Resupply at 10% of Initial
42	Wipes, Dry	4	0.004	0.40					0.1		
43	Wipes, Wet	4	0.008	0.40					0.1		
44	Failed Hardware Replacements (10%)		4.248	1699.60							
45	Hardware For Changeout (2.5%)		1.062	424.90							
46											
47	TOTALS		22.126	8164.38							Vol includes 20% for packing matls
48											
49											

TABLE LSRF-3. MATERIALS RETURN

		PAYLOAD TOTALS				ITEM CHARACTERISTICS					
	EQUIPMENT NAME	QTY Reqd	VOL cu m	MASS kg	POWER watts	DEPTH m	WIDTH m	HEIGHT m	MASS kg	POWER watts	REMARKS
1	Food Trays, Mouse	416	0.830	374.40					0.9		
2	Food Trays, Rat	885	1.800	796.50					0.9		
3	Modular Habitat (Rat)	32	2.000	960.00					30		
4	Samples, Ambient or Refrigerared		0.160	120.00							
5	Samples, Ambient or Refrigerated		0.439	45.00							
6	Samples, Frozen		0.060	6.40							
7	Samples, Frozen		0.123	20.00							
8	Specimen (Expired Mice)	148	0.029	4.43					0.0299		In Freezer
9	Specimens (Expired Rats)	128	0.055	78.63					0.61429		
10	Specimens (Live Mice)	112	0.000	1.70					0.01518		
11	Specimens (Live Rats)	32	0.000	0.80					0.025		In Modular Habitats
12	Waste Trays, Mouse	416	0.830	374.40					0.9		
13	Waste Trays, Rat	885	1.800	796.50					0.9		
14	Waste, Liquid		0.423	422.70							
15	Waste, Liquid (Cage Washer)	205	0.200	205.00					1		
16	Waste, Liquid (Mice)		0.040	43.60							
17	Waste, Liquid (Rats)		0.628	628.00							
18	Waste, Solid		1.550	260.95							Wipes, 25% of food,10% vld tps
19	Waste, Solid		3.589	883.40							
20	Waste, Solid (Mice)		0.000	6.50							In Waste Tray
21	Waste, Solid (Rats)		0.000	100.00							In Waste Tray
22	Failed Hardware (10%)		3.872	1424.26							
23	Changed out Hardware (2.5%)		0.968	356.07							
24											
25	TOTALS		23.275	7899.23							Vol includes 20% for packing matls
26											
27											

upgrade/change experiments; and resupply of stowed expendables every 90 days.

a. Consumables Replenishment

The LSRF Project has developed a detailed listing of all experiments to be performed for the full 39 m^3 rack complement of the desired LSRF capability and has estimated, based on Spacelab experience, the crew time required on an equipment-by-equipment basis to replenish all animal consumables/expendables and remove waste. The findings of this analysis are presented in the LSRF RMOAD (see Bibliography) which results in the following requirement:

Activity	Elapsed Time (hr:min)	IVA Time (crew-hr:min)	EVA Time (crew-hr:min)	Robotics Time (hr:min)
BRP consumables replenishment and waste removal	2293:00 per year	2293:00 per year	0:00	0:00

b. Equipment change-out

Every 90 days, it is assumed that 10% (by mass) of the 140 separate pieces of rack-mounted equipment will be changed-out for failure, and 2.5% (by mass) will be changed-out for upgrade/change. This will result in a total change-out of 2125 kg, and the following associated requirement:

Activity	Elapsed Time (hr:min)	IVA Crew-hours (hr:min)	EVA Crew-Hours (hr:min)	Robotics Time (hr:min)
Change-out	7:00^	14:10^	0:00	0:00

All estimates assume that rack change-outs are done in double-rack units, and that the average double-rack unit contains 600 kg of equipment.

c. Resupply of Stowed Expendables

Every 90 days, expendables and waste which have been accumulated must be removed, and new supplies must be stowed in the LSRF from the logistics module. It is assumed (see Table LSRF-3) that 6039 kg of stowed material will be changed-out during a typical mission resulting in the following requirement:

Activity	Elapsed Time (hr:min)	IVA Crew-Hours (hr:min)	EVA Crew-Hours (hr:min)	Robotics Usage (hr:min)
Resupply Stowed Materials	4:30^	9:00^	0:00	0:00

13.4 Close-Out Servicing Time Estimates

No close-out servicing activities are identified. (The loading of the Orbiter with the Logistics Module is considered Space Station operations).

14.0 LSRF STRAWMAN SERVICING SCENARIO

14.1 LSRF STRAWMAN SERVICING MISSION

The strawman LSRF servicing mission assumes that the full $39m^3$ LSRF equipment capability is in place and that servicing consists of continuous resupply of consumables and removal of waste for the animal/plant specimens, and at each 90 day logistics flight interval, change-out of equipment and replenishment of consumables and stowed materials.

14.2 LSRF Description

LSRF is contained within the continuously manned, pressurized U.S. Laboratory and its resource nodes. The overall physical characteristics are listed in Section 2.2.

14.3 Strawman Servicing Materials

Table LSRF-3 summarizes the strawman materials assumed for the strawman mission, including resupply and removal. These materials consist of a combination of ORUs, consumables, and stowed materials.

a. ORUs

LSRF ORUs consist of the experimental rack-mounted equipment. Current plans call for replacing an estimated 10% of the equipment (by mass) due to failure, and approximately 2.5% (by mass) for change-out. For the purpose of this scenario, the following equipment is assumed to fail and/or require change-out:

(1) FAILED EQUIPMENT

Item	Number	Mass (kg)	Total Mass (kg)
Refrigerator	2	140	280
Video recorder	1	15	15
Cage cleaning system	1	100	100
Cardiopulmonary flow meter	1	42	42
Standard centrifuge	1	30	30
Rotator	1	40	40
Hand wash facility	1	100	100
Blood gas analyzer	1	45	45
Video system	1	180	180
Small rodent modular habitat	10	30	300
Primate modular habitat	1	150	150
Plant modular habitat	3	120	360
Habitat monitoring system	5	20	100

(2) EQUIPMENT FOR CHANGE-OUT

Item	Number	Mass (kg)	Total Mass
Small Rodent holding facility	2	150	300
Gamma Counter	1	183	183

The requirement to support the servicing for these LSRF ORUs is as follows:

Activity	Mass (kg)	Volume (m^3)	Elapsed Time (hr:min)	IVA Time (crew-hr:min)	EVA Time (crew-hr:min)	Robotics Time (hr:min)
Replace failed ORUs	1742	3.0	5:20^	10:40^	0:00	0:00
Change-out ORUs	483	0.9	1:40^	3:30^	0:00	0:00
Total	2225	3.9	7:00^	14:10^	0:00	0:00

In addition to ORU servicing, LSRF consumables and stowed materials require servicing. From Table LSRF-3, the requirement is as follows:

Activity	Mass (kg)	Volume (m^3)	Elapsed Time (hr:min)	IVA Time (crew-hr:min)	EVA Time (crew-hr:min)	Robotics Time (hr:min)
Resupply Consumables and stowed materials and remove waste and expendables	6039	18.2	4:30^	9:00^	0:00^	0:00^

b. Flight Support Equipment (FSE)

30 kg of LSRF tools will be stowed within the facility and, if required, changed-out as part of the stowed equipment.

c. Consumables and Containers

1. 90 Day Resupply

LSRF consumables consist of the food and water for the animal and plant specimens and water for habitat cleaning. The mass, volume, and dimensions of the consumables are listed in Table LSRF-3, and the IVA requirement for resupplying these items is contained in section a above within the stowed and consumables resupply estimate.

2. Continuous Resupply

The animal and plant consumables require continuous resupply between the 90 day logistics flights. This activity has been estimated by the LSRF project to require 573 IVA hours per quarter.

14.4 Estimated Up/Down Mass on STS to Support LSRF Strawman Servicing*

SERVICING MATERIAL	MASS UNPRESSURIZED TRANSPORT (kg)	MASS PRESSURIZED TRANSPORT (kg)	MASS TOTAL (kg)
Equipment**			
SI(s)	0	0	0
ORU(s)	2225/1880	0	2225/1880
Unique FSE	0	0	0
Misc. Equipment	3963/4297	1053/1045	5016/5342
Equipment Subtotal	6188/6177	1053/1045	7241/7222
Equipment Carrier(s)***	0	0	0
Subtotal, Equipment Mass Up	6188	1053	7241
Subtotal, Equipment Mass Down	6177	1045	7222
Consumables****			
Consumables	1025/777	0	1025/777
Consumables Containers	0	0	0
Consumables Containers' Carriers***	0	0	0
Subtotal, Consumables Mass Up	1025	0	1025
Subtotal, Consumables Mass Down	777	0	777
Total Mass Up	7213	1053	8266
Total Mass Down	6954	1045	7999

* Double entries indicate mass up/mass down.

** ORUs consist of failed hardware and changed out hardware; pressurized misc. equipment consists of specimen habitats and specimens (live or expired); and unpressurized misc. equipment consists of all other items except consumables.

*** The Space Station Logistics Module is assumed to represent the LSRF carrier for all materials.

**** Consumables consist of specimen food, water, and liquid and solid waste.

14.5 Estimated Up/Down Volume on STS to Support LSRF Strawman Servicing

SERVICING MATERIAL	VOLUME, UNPRESSURIZED TRANSPORT (m^3)	VOLUME, PRESSURIZED TRANSPORT (m^3)	VOLUME, TOTAL (m^3)
Equipment			
SI(s)	0	0	0
ORU(s)	5.3/5.0	3.3/2.1	8.6/7.1
Unique FSE	0	0	0
Misc. Equipment	9.9/12.6	0	9.9/12.6
Equipment Subtotal	15.2/17.6	0	18.5/19.7
Consumables			
Consumables	1.0/1.0	0	1.0/1.0
Consumables, Containers, and Carriers	3.6/3.6	0	3.6/3.6
Total Volume Up	18.8	3.3	22.1
Total Volume Down	21.2	2.1	23.3

14.6 Storage on Space Station Required to Support Strawman LSRF Servicing

Continuous Storage	Unpressurized	Pressurized	Total
Mass (kg)	7213	1053	8266
Volume (m^3)	18.8	3.3	22.1
Average Power (watts)	0	0	0
Temperature Range (°C)	0	20 to 25°C	0
Temporary Storage			
Mass (kg)	0	0	0
Volume (m^3)	0	0	0
Average Power (watts)	0	0	0
Temperature Range (°C)	-	-	-

14.7 LSRF Strawman Servicing Power Estimate

	Operational Mode (watts) Avg	Max	Servicing Mode (watts) Avg	Max
LSRF	9.5 kW	TBD	To be conducted within available operational power.	

14.8 LSRF Strawman Servicing Times

Activity	Elapsed Time (hr:min)	IVA Time (crew-hr:min)	EVA Time (crew-hr:min)	Robotics Time (hr:min)
1. Replace failed ORUs and changeout equipment	7:00^	14:10^	0:00^	0:00^
2. Resupply stowed and consumable materials and remove waste	4:30^	9:00^	0:00^	0:00^
TOTAL 90 day Servicing:	11:30^	23:10^	0:00^	0:00^

Continuous Servicing: 573 IVA hours per quarter.

14.9 OMV Flights in Support of LSRF Strawman Servicing

LSRF requires no OMV support.

15.0 OVERALL REQUIREMENTS SUMMARY FOR SS SERVICING OF LSRF

15.1 LSRF Milestones and Servicing Schedule

Event	Location	Date
LSRF Launch	KSC	1st quarter, 1995
Servicing	SS-attached	every quarter
Payload Mission Termination		2015-2025

15.2 Summary of LSRF Mass Considerations

a. LSRF Mass
Servicing and Operational Mass: 11,650 kg

b. LSRF Servicing Mass Up and Down in STS*

Event	Mass Up (kg)	Mass Down (kg)
Launch	Incremental build	Incremental build
1st through 44th servicing missions**	363,704	351,956
Termination	0	11,650
Totals	375,354	363,606
SS Servicing Total	363,704	351,956

* This represents the requirements through the year 2005, i.e., only 11 years of LSRF's planned lifetime of 20-30 years.

** Based on 8266 kg mass up and 7999 kg mass down for each servicing mission.

c. LSRF Servicing Storage Mass on Space Station

	Storage Mass (kg)		
Calendar Year	Unpressurized	Pressurized	Total
1995	7213	1053	8266
1996	7213	1053	8266
1997	7213	1053	8266
1998	7213	1053	8266
1999	7213	1053	8266
2000	7213	1053	8266
2001	7213	1053	8266
2002	7213	1053	8266
2003	7213	1053	8266
2004	7213	1053	8266
2005	7213	1053	8266

15.3 Summary of LSRF Volume considerations

a. LSRF Volume
Operational/Servicing/Transportation Volume: 70 m^3
(pressurized module envelope)

b. LSRF Servicing Volumes Up and Down in STS*

Event	Volume Up (m^3)	Volume Down (m^3)
Launch	Incremental build	Incremental build
1st through 44th** servicing missions	972.4	981.2
Termination	0	39
Totals	1,011.4	1,020.20
SS Servicing Total	972.4	981.2

* This represents the requirements through the year 2005, i.e., only 11 years of LSRF's planned lifetime of 20-30 years.

** Based on 22.1 m^3 volume up and 22.3 m^3 volume down for each servicing mission.

c. LSRF Servicing Storage Volume on Space Station

	Storage Volume (m^3)		
Calender Year	Unpressurized	Pressurized	Total
1995	18.8	3.3	22.1
1996	18.8	3.3	22.1
1997	18.8	3.3	22.1
1998	18.8	3.3	22.1
1999	18.8	3.3	22.1
2000	18.8	3.3	22.1
2001	18.8	3.3	22.1
2002	18.8	3.3	22.1
2003	18.8	3.3	22.1
2004	18.8	3.3	22.1
2005	18.8	3.3	22.1

15.4 Summary of LSRF Power Considerations

	Average	Maximum
MMPF Operational Power (watts)	9500	TBD
MMPF Servicing Power (watts), and Storage Power for Servicing Materials (watts)	Within available operational power	TBD

15.5 Summary of LSRF Servicing Time Estimates

Calendar Year	95	96	97	98	99	00	01	02	03	04	05	TOTAL
Elapsed Time (hr:min)	46:00	46:00	46:00	46:00	46:00	46:00	46:00	46:00	46:00	46:00	46:00	506:00
IVA Time (Crew-hr:min)	92:40	92:40	92:40	92:40	92:40	92:40	92:40	92:40	92:40	92:40	92:40	254:50
EVA Time (Crew-hr:min)	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Total Crew-Time (hr:min)	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
MRMS Time (hr:min)	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Note: Totals do not reflect the data values which are TBD.

15.6 Summary of OMV Flights in Support of LSRF SS Servicing

LSRF requires no OMV support.

LSRF REFERENCES

Document

(1) Reference Mission Operational Analysis Document (RMOAD) for the Life Sciences Research Facilities, Revised, February 1987, NASA TM 89604.

(2) Discussion (and data review) with L. Chambers (NASA/HQ), August, 1987.

(3) Review comments, G. Primeaux (NASA/JSC) September 15, 1987.

(4) Discussion with Dr. Machaud (RCA, (713) 488-9005) concerning RMOAD servicing estimates.